

+ HOW TO LIVE BEYOND 100 THE NEW SCIENCE HELPING US TO BREAK THE AGE LIMIT

# HOW IT WORKS

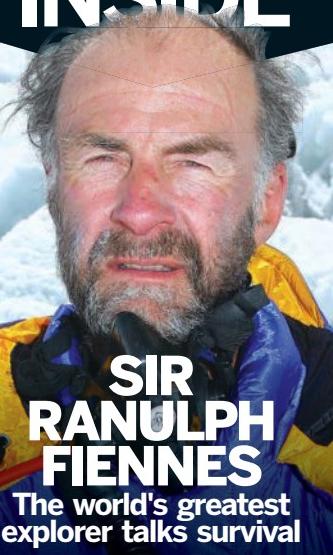
SCIENCE ENVIRONMENT TECHNOLOGY PORT HISTORY SPACE

## A TRAVELLER'S GUIDE TO THE SOLAR SYSTEM

Join us on an epic voyage of the must-see sights



INSIDE



SIR  
RANULPH  
FIENNES

The world's greatest explorer talks survival

942  
FACTS AND  
ANSWERS  
INSIDE

100 YEARS OF WARFARE

# TANKS

THE EVOLUTION OF ARMOURED BATTLE,  
FROM WWI TO MODERN MECHANISED MARVELS



### VENUS FLYTRAP

How this killer plant catches its prey



### TEETH WHITENING

The science behind your sparkling new smile

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ISSUE 85

### LEARN ABOUT

- BRUISES ■ INFINITY POOLS
- BBQ SCIENCE ■ FROG LIFE CYCLE
- TUDOR MAKE-UP ■ BREATHING



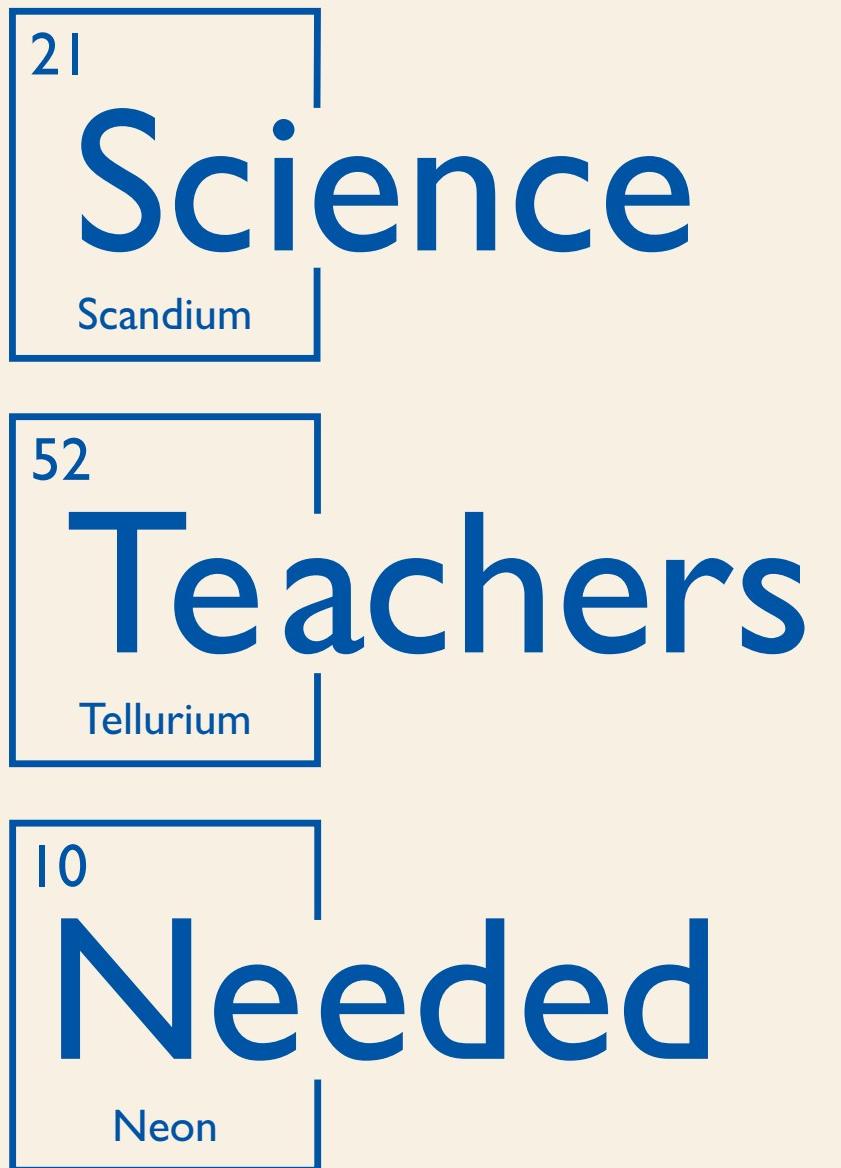
### ARTIFICIAL ISLANDS

The engineering behind a pop-up paradise



### FOOD BLENDERS

Inside the vortex of this kitchen essential



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# WELCOME

The magazine that feeds minds!

ISSUE 85



**"We couldn't eat, drink or contact the outside world"**

Polar explorer Ann Daniels, page 43

## Meet the team...



**Jo**

**Features Editor**

Chatting to Sir Ranulph and Ann Daniels was hugely inspiring, but I think I'd still rather choose the beach over the North Pole for my next trip!



**Jackie**

**Research Editor**

Who wants to live forever? Our feature on page 24 reveals the cutting-edge anti-ageing science that will help us to live longer and healthier lives.



**Katy**

**Production Editor**

If you like to plan ahead, have a read of our space travel brochure from the future - do you fancy stormy Jupiter, scorching Venus or icy Enceladus?



**Duncan**

**Senior Art Editor**

Tanks for buying HIW, this really is an explosive issue, especially the celebration of 100 years of tanks, which is reason enough to shell out on the mag!



**Briony**

**Assistant Designer**

Happen to have a spare 100,000 plastic bottles? Then head to page 50 and learn how to make your very own floating island.



"Ideals are peaceful. History is violent," says Brad Pitt's Wardaddy in the tank-epic *Fury*. Set in 1945, the film follows a brotherhood of GIs and a Sherman tank they call home. These mechanised monsters had come a long way since the tin bathtubs of WWI, but the technology and armour was nothing compared with the remote-controlled stealth vehicles that storm the modern battlefield.

This year, we mark the centenary of the tank with a feature that explores the evolution of this war-changing weapon. Also in this issue, we learn the secrets of survival from the greatest living explorer, Sir Ranulph Fiennes, and relive history's most incredible voyages. See the rickety vessels that took early adventurers to the coldest, deepest and most out-of-this-world places, and read real-life accounts.

On top of that, we have a special report on how scientists are striving to help us live longer, and the incredible research that will preserve our planet for future generations. Be inspired!

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**Jodie Tyley**  
Editor

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## Meet the experts...



### Laura Mears

Science writer Laura tackles the hot topic of how we live beyond 100. It's a fascinating area of research that has already seen the lifespan of mice significantly increased. Get the lowdown over on page 24.



### Michael Haskew

The author of our cover feature has been writing and researching military history for over 25 years and has recently released a new book, *Tanks Inside Out*.



### Kat Arney

With a degree in natural sciences and a PhD in developmental biology, Dr Kat Arney is now a regular contributor to our science section. This month, she explains the process of respiration on page 28.



### Ella Carter

Nature writer Ella reveals how Canada's Spotted Lake got its magnificent pattern, the deadly contraption of the Venus flytrap, and the life cycle of a frog.



### Alicea Francis

All About History's Editor takes us to a Victorian workhouse and reveals how close Oliver Twist was to the brutal conditions inside.



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## 100 YEARS OF TANKS



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# Death-defying journeys

Incredible voyages and the secrets of survival



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**SUBSCRIBE NOW!**  
Go to page 92 for great deals

# The hoverboard you can actually buy

Finally! A board that flies over rocky terrain and water

 When Lexus unveiled its futuristic Slide hoverboard in 2015, the world was

disappointed to discover that it could only hover over a special magnetic track, and would not be available to buy. This year, however, the *Back To The Future II* vision has finally become reality, as the ARCA Space Corporation has unveiled a commercially available device that can hover above any terrain.

The ArcaBoard uses 36 high power electric ducted fans to create enough thrust to lift it up to 30 centimetres off the ground. The fans are driven by electric motors, with each one powered by its own lithium-ion polymer battery. This means that if multiple batteries or motors fail, the board will have enough working fans to keep it in the air. The

outer frame is made from aerospace grade composite structures, making it incredibly lightweight, and there's a built-in stabilisation system to aid balance. When switched on, it enables you to control the board with your phone via Bluetooth, but you can also switch it off to steer with your body, just like on a skateboard. Proximity sensors limit the ArcaBoards's top speed to 20 kilometres per hour, and keep it steady if you accidentally fall off mid-flight.

Unfortunately it can currently only hover for six minutes on a single charge, but the special ArcaDock wireless charger will get it back to full power in just 35 minutes. In total, this package will set you back \$19,900 (about £13,900), and the first boards are due to start shipping in April 2016.





## Inside the ArcaBoard

How does this futuristic platform help you hover?

### Frame

The inner workings are encased within a lightweight frame made from composite structures.

### Batteries

The batteries' 203,000 watts of electricity generate 272 horsepower.

### Fans

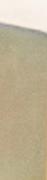
Along with the batteries, the 36 electric ducted fans occupy 90 per cent of the space inside the board.

### Motors

Each fan is driven by a battery-powered motor, so if one fails, there are enough spares to keep it in the air.

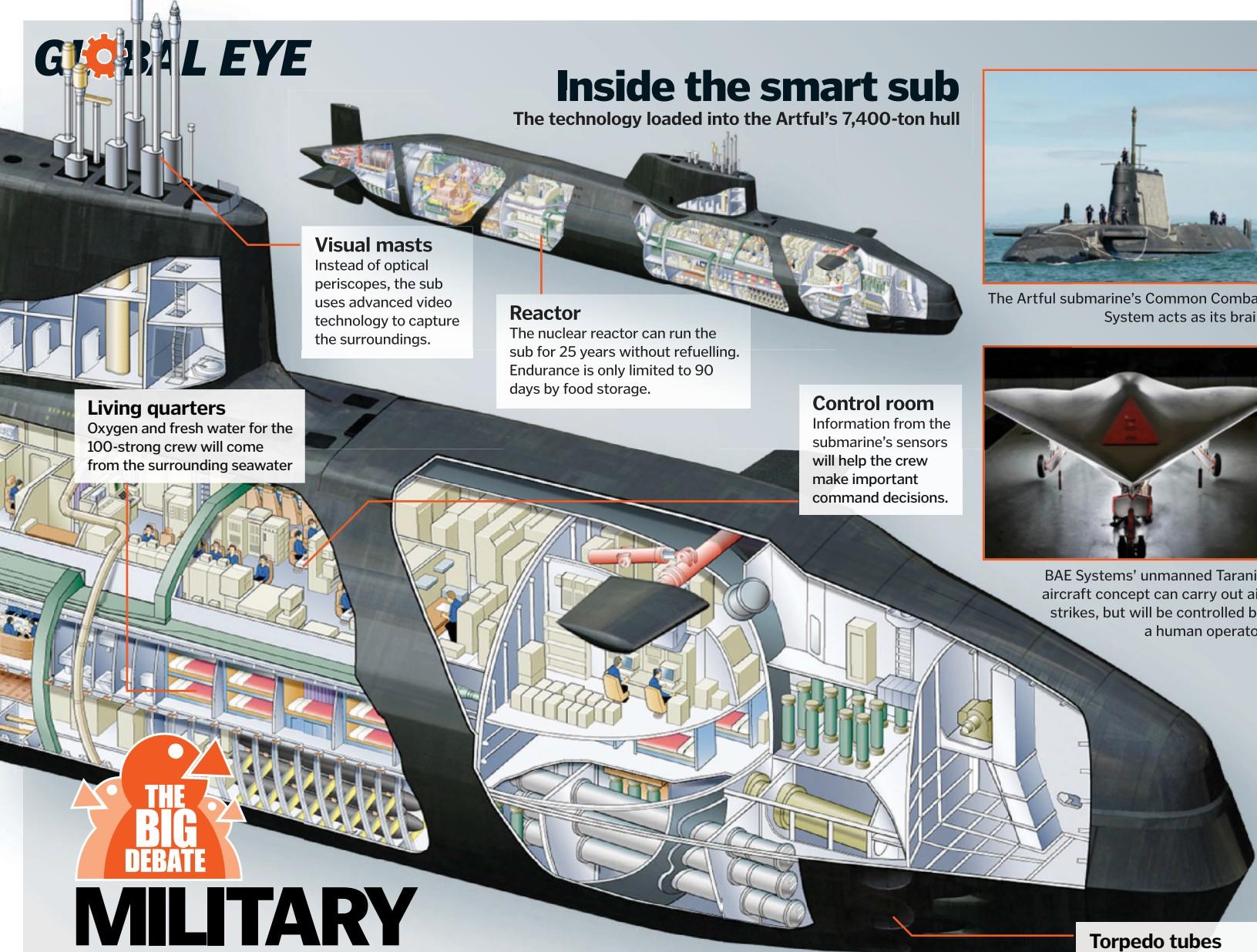
### Control

The board can be controlled via Bluetooth, letting you steer and adjust the elevation with your phone.



## Inside the smart sub

The technology loaded into the Artful's 7,400-ton hull



### LIVING QUARTERS

Oxygen and fresh water for the 100-strong crew will come from the surrounding seawater

### Visual masts

Instead of optical periscopes, the sub uses advanced video technology to capture the surroundings.

### Reactor

The nuclear reactor can run the sub for 25 years without refuelling. Endurance is only limited to 90 days by food storage.

### Control room

Information from the submarine's sensors will help the crew make important command decisions.

The Artful submarine's Common Combat System acts as its brain



BAE Systems' unmanned Taranis aircraft concept can carry out air strikes, but will be controlled by a human operator

### THE BIG DEBATE

# MILITARY ROBOTS

Get to grips with the issue that has scientists and inventors worried



The HMS Artful, the Royal Navy's latest and most advanced submarine, has fired a torpedo using its own 'brain'. Its

Common Combat System uses a set of sensors that act as eyes, ears and a nervous system to interpret sonar readings and attack a moving target. Currently, the final decision about whether or not to fire is down to the human crew members, but the possibility of it being able to bypass their input and think for itself may not be very far off.

This has caused a group of prominent leaders in the world of science and tech to call for a ban on the use of autonomous weapons. Astrophysicist Stephen Hawking, Tesla Motors Inc founder Elon Musk and Apple Inc co-founder Steve Wosniak have all signed a letter labelling AI weapons as "the third revolution in warfare",

following gunpowder and nuclear arms, and claim that they could result in an arms race more dangerous than the Cold War.

However, inventor and entrepreneur James Tagg believes this future is a long way off. "The digital computers that we have today can sort of think for themselves. They can make some fairly simple decisions and play games quite well," he explains. "The thing they can't do is be creative and have free will. They're deterministic machines. So the biggest problem we have today is that we don't know the basic science of how we would make machines that have true artificial intelligence."

Nevertheless, he believes that giving any sort of machine the power to kill is dangerous. "The basic ethics are the same for all types of artificial intelligence, whether it's creative or not. If you engineer something that has full free

James Tagg believes it will be a while before computers are able to have free will

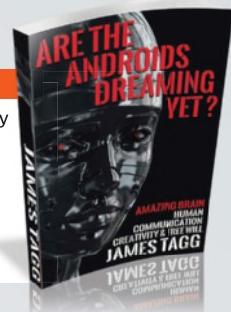


will then you might give it rules to stop it from doing something you consider bad and it may decide to ignore them. On the other hand, a deterministic machine that obeys the rules may have bugs in it and get those rules wrong."

**"We don't know the basic science of how we would make machines that have true artificial intelligence"**

### Learn more

Find out more about the possibility of creating true artificial intelligence in James Tagg's new book. *Are the Androids Dreaming Yet?* explores the limitations of computers to be creative and exercise free will.




**NEWS BY  
NUMBERS**

# 7,080 km

The record-breaking distance flown by the Pantala flavescens dragonfly

# 1,000 photos

tweeted by astronaut Scott Kelly during his year-long mission on the ISS

# 420 km/h

The top speed of the Bugatti Chiron, the world's most powerful production car

# 15,000

The number of HTC Vive VR headsets sold in the first ten minutes of going on sale



## Laser weapon technology

Testing is underway to see just what it can do on the battlefield



The US Army claims it is "very close" to deploying laser weapons in combat.

Extensive tests are being carried out to evaluate how high-energy lasers can be used against a variety of threats, including rockets, drones and cruise missiles. The US Air Force is already employing lasers for defensive purposes, using infrared to confuse enemy missile guidance systems, but is now working on an offensive laser that will be fitted to AFSOC AC-130 gunships. The laser programme is already planned and funded for delivery by 2023.

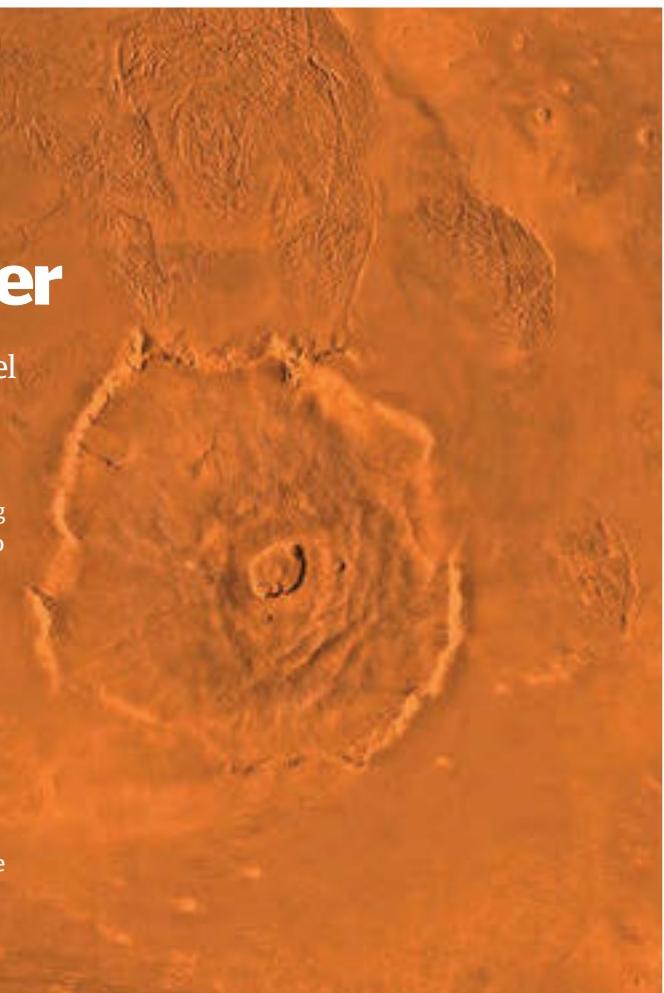
## Volcanic eruptions changed Mars forever

Billions of tons of lava caused the surface to swivel



Over three million years ago, a billion billion tons of lava spewed from the

Tharsis volcanoes on Mars, causing the planet's outer layers to tilt by 20 to 25 degrees. Geomorphologist Sylvain Bouley and his team at Université Paris-Sud, France, used computer models to try to understand why underground reservoirs of ice were not closer to the poles, and found that they had been nearer previously. They concluded that if a similar shift happened on Earth, Paris would be in the Arctic circle.



## Secrets of black widow markings revealed

The toxic spider's tell-tale symbol is ingeniously hidden from insect eyes



The red hourglass shape on a black widow is less visible to insect prey



Venomous female black widow spiders are easily identifiable by a signature red hourglass shape on their belly.

This symbol helps to warn would-be predators, such as birds, to stay away, but doesn't blow their cover to their insect prey. Researchers at Duke University have discovered that this is because birds' eyes are more sensitive to the colour red than those of insects. The spiders also usually hang underneath their webs with their bellies facing the birds above, obscuring their markings from the insects below.

# GLOBAL EYE

# 10 COOL THINGS WE LEARNED THIS MONTH



## Praying mantises can see in 3D

Scientists at Newcastle University have fitted praying mantises with tiny 3D glasses to prove they have stereovision, just like us. They showed the insects videos of bugs moving just beyond their reach, and when viewing in 2D, they didn't react. However, during the 3D showing they struck out, believing the bug was within their grasp and proving that they can perceive the distance between themselves and their prey.

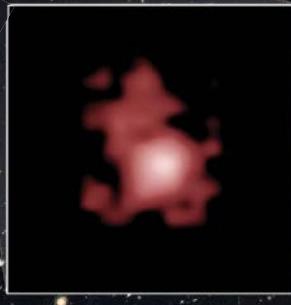
## Your future car could run on poo

The United States produces over a billion tons of manure every year, and researchers at the University of California are hoping to turn it into advanced biofuels. By engineering the metabolisms of bacteria that normally use the protein in poo to grow, they can instead get them to turn it into alcohols that burn just like gasoline.



## Hubble has spied the furthest known galaxy

Using the Hubble Space Telescope, an international team of astronomers has been able to see 13.4 billion light years into the past. That's how long it has taken the light from GN-z11, the furthest galaxy ever observed in the universe, to reach Earth. This means that the team can see the galaxy at a time when the universe was just 400 million years old.



## Alligators help protect birds' nests

In the Florida wetlands, birds such as storks and herons often build their nests above alligator hotspots, as the reptiles help to keep raccoons away from their eggs. Now scientists at the University of Florida have found that the alligators benefit too. As the birds typically hatch more chicks than they can provide for, some die and end up in the water, providing the gators with food.





## The grey hair gene has been found

For the first time, a gene involved in greying hair has been found in humans, proving that it is a genetic process, not just environmental. A team of international scientists analysed over 6,000 people to identify the IRF4 gene, and now want to find out exactly how it influences greying in the hope that they may be able to slow or block the process.



## Downloading pilots' brainwaves could help you learn to fly

Just as in the sci-fi film *The Matrix*, it may well be possible to download skills and become an instant expert. Researchers at HRL Laboratories LLC found that by measuring the brain activity patterns of trained pilots and transmitting them to electrode-embedded head caps worn by novice pilots in a flight simulator, they could improve the beginner's piloting abilities.



## Happiness can break your heart

Researchers at University Hospital Zurich have discovered that Takotsubo cardiomyopathy, also known as broken heart syndrome, can be caused by joyful events as well as negative ones. Birthday parties and the birth of a grandchild have both been found to cause the sudden weakening of heart muscles.

**Summers on Titan are really cold**

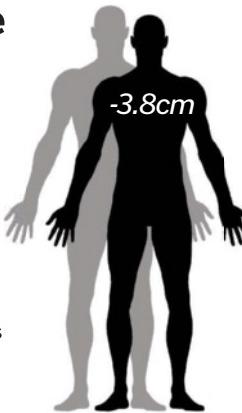
Since arriving in Saturn's orbit in 2004, NASA's Cassini spacecraft has been regularly taking the temperature of the planet's moons, and has found Titan's climate changes slowly over the course of its 7.5-year-long seasons. In the peak of summer, Titan's southern hemisphere is -179.6 degrees Celsius, and the northern pole is only 3.5 degrees colder, but warmer temperatures shift north as winter approaches.

**"Titan's southern hemisphere is -179.6 degrees Celsius"**



## A year in space made Scott Kelly taller

After spending 340 days aboard the International Space Station, the longest continuous stay in space by a US astronaut, Scott Kelly's height increased by 3.8 centimetres. Life in microgravity caused his spine to elongate, but he has since returned to normal size back on Earth. He also claims it has made his skin "very sensitive" because "it hadn't touched anything for so long".



© Newcastle University/NASA/Thinkstock

## The electric skateboard speed record has been set

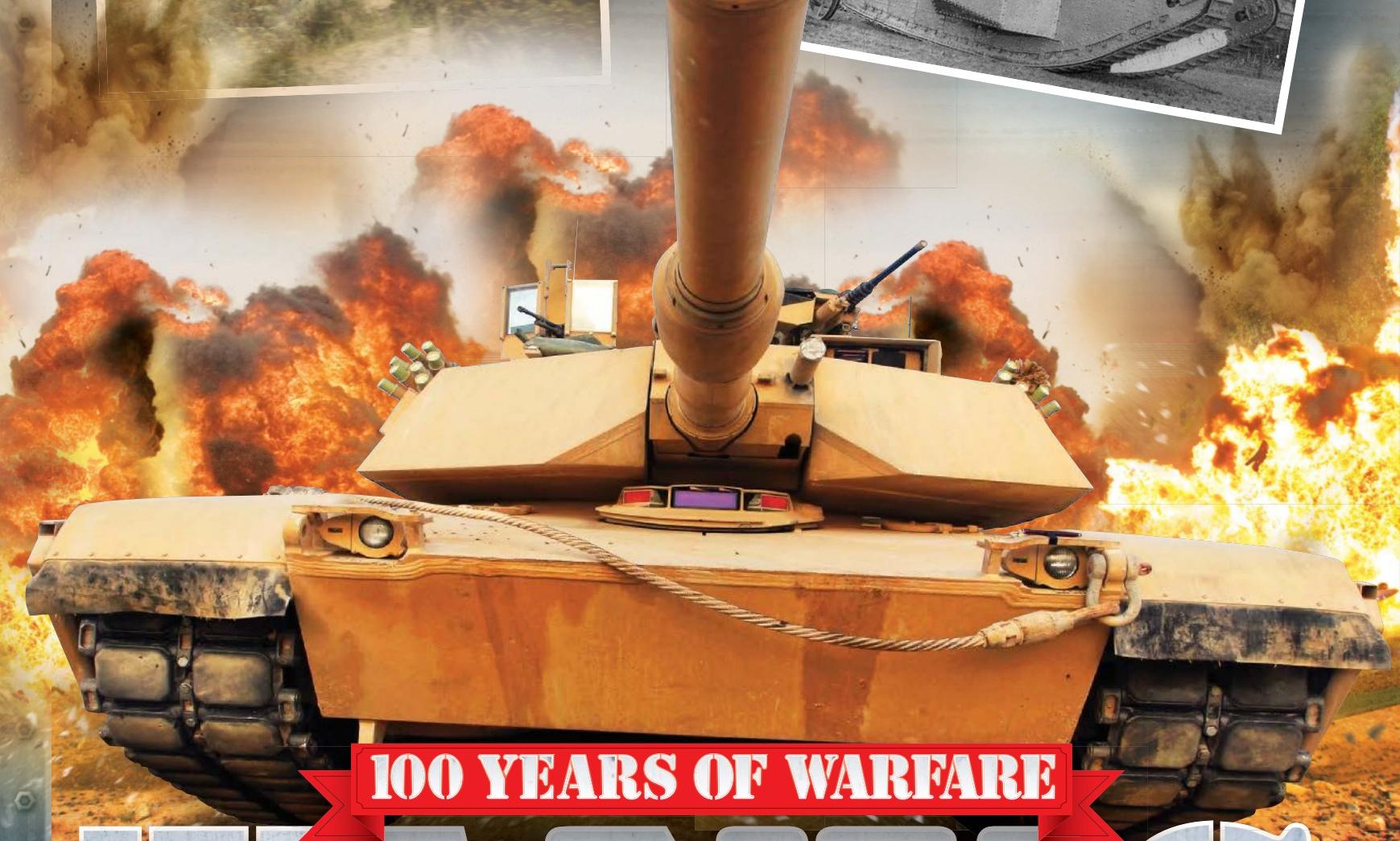
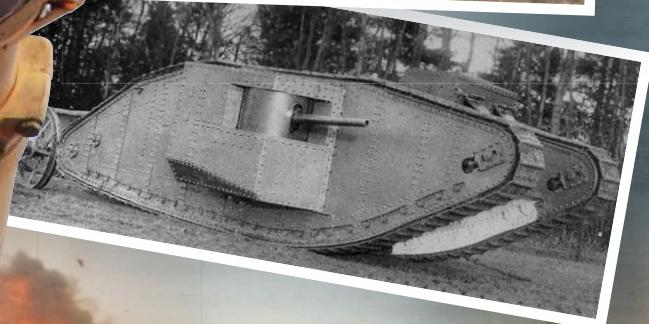
Using a modified longboard powered by a motor in each wheel, 32-year-old daredevil Mischo Erban has set a new Guinness World Record for fastest speed on an electric skateboard, reaching 95.83 kilometres per hour on an empty airport runway in Slovenia.

FASTEST BIRD (IN LEVEL FLIGHT)	Grey-headed albatross <b>127km/h</b>
FASTEST LAND MAMMAL	Cheetah <b>98km/h</b>
FASTEST FISH	Cosmopolitan sailfish <b>109km/h</b>
FASTEST ELECTRIC SKATEBOARD	Mischo Erban <b>95.83km/h</b>





TRANSPORT



100 YEARS OF WARFARE

# TANKS

THE EVOLUTION OF ARMoured BATTLE,  
FROM WWI TO MODERN MECHANISED MARVELS

**A**ncient Greek hoplites joined their shields and advanced in unison. Hannibal's Carthaginians mounted war elephants. The visionary Leonardo da Vinci rendered an image of an armoured fighting vehicle in 1487. While the concept of the tank - an armoured unit that could dominate the battlefield - has existed for almost as long as mankind has waged war, it became workable and developed to devastating capability 100 years ago.

Since the creaky bathtubs of World War I, the tank has existed to provide an operational edge during combat. Its varied roles range from the hammer blow of the mailed fist to break through enemy lines, to the rapid exploitation of the breach and the destruction of other vehicles and fortifications, as well as reconnaissance and fire support as mobile artillery.

To successfully complete the assigned mission, tanks require three key design elements: firepower, mobility and protection. Concentrated firepower punches a hole through enemy lines, while being able to tackle any type of terrain at speed enables them to travel over enemy trenches, and heavy armour shields the crew that supplies the expertise, efficiency, and courage to go in harm's way.

When the tank entered combat for the first time, hopes were high that the horrific stalemate of trench warfare would be broken. While the tank matured as an armament system, it became a weapon of dominance and decision. Today, the tank is perceived both as a potential war winner and a costly machine that may be past its prime. Regardless, the technological advancements and its impact on warfare are nothing short of astonishing.

Without question, the mere existence of the tank continues to influence any decision to wage war and any effective defence against an attacker on land. The tank, therefore, remains a prime shaper of military strategy and will continue to be into the foreseeable future.

Challenger 2 is equipped with a highly accurate fire control system



# TANKS THROUGH HISTORY

Over decades of warfare, technology has shaped tanks into weapons of awesome power



**Mark V (Male)**

Country of origin:  
United Kingdom  
First produced: 1917  
Still in service? No



**Char B1 bis**

Country of origin:  
France  
First produced: 1937  
Still in service? No



**Centurion**

Country of origin:  
United Kingdom  
First produced: 1945  
Still in service? No



**M60**

Country of origin:  
United States  
First produced: 1959  
Still in service? Yes



**PT-76**

Country of origin:  
Soviet Union  
First produced: 1950  
Still in service? Yes



**T-54**

Country of origin:  
Soviet Union  
First produced: 1948  
Still in service? Yes



**T-72**

Country of origin:  
Soviet Union  
First produced: 1971  
Still in service? Yes



**Leopard 2**

Country of origin:  
Germany  
First produced: 1979  
Still in service? Yes



**M1A1 Abrams**

Country of origin:  
United States  
First produced: 1979  
Still in service? Yes



**Challenger 2**

Country of origin:  
United Kingdom  
First produced: 1993  
Still in service? Yes



**Arjun**

Country of origin:  
India  
First produced: 2004  
Still in service? Yes



**K2 Black Panther**

Country of origin:  
South Korea  
First produced: 2013  
Still in service? Yes



**T-90**

Country of origin:  
Russia  
First produced: 1993  
Still in service? Yes



The T-72 tank has been exported to over 30 countries





# TANKS PAST AND PRESENT

## How the demands of the modern battlefield have shaped designs

Prior to World War I, research and development yielded some practical benefits in tank design. Caterpillar treads, already in use with heavy tractors, proved superior to wheels, and power to weight ratios were recognised as having significant impact on mobility and performance.

Experimentation with every aspect of the tank's development led to the introduction of basic internal power plants, and sheets of steel were riveted together to form armoured boxes on top of a tractor or car chassis. Visibility and steering were crudely accomplished with

hazardous viewing ports and a series of tillers respectively. Machine guns and cannon originally meant for use with infantry and artillery units were also adapted.

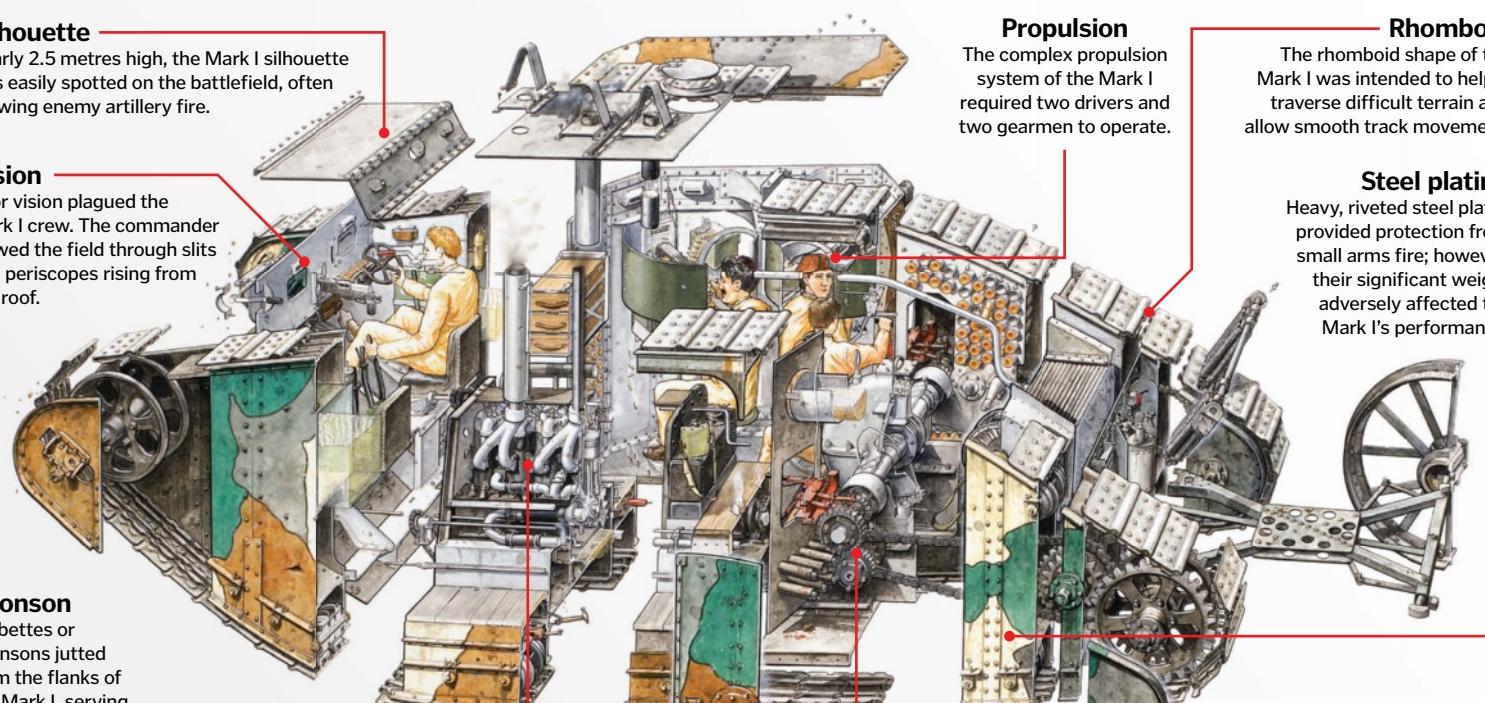
Although they were terrifying to the common foot soldier that encountered them, the earliest

### Silhouette

Nearly 2.5 metres high, the Mark I silhouette was easily spotted on the battlefield, often drawing enemy artillery fire.

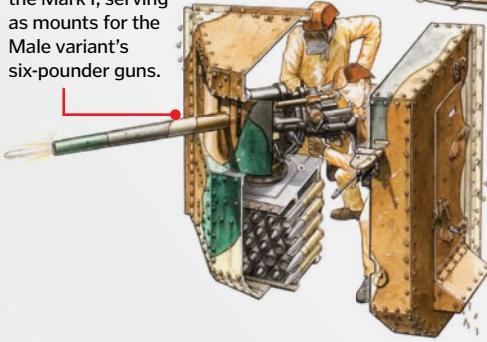
### Vision

Poor vision plagued the Mark I crew. The commander viewed the field through slits and periscopes rising from the roof.



### Sponson

Barbettes or sponsons jutted from the flanks of the Mark I, serving as mounts for the Male variant's six-pounder guns.



### Engine

The 105-horsepower, six-cylinder Foster-Daimler sleeve valve engine of the Mark I generated a top speed of around six kilometres per hour.

### Machine guns

At least three 7.7mm Hotchkiss or Vickers machine guns were mounted on both the Male and Female Mark I variants.

### Propulsion

The complex propulsion system of the Mark I required two drivers and two gearmen to operate.

### Rhomboid

The rhomboid shape of the Mark I was intended to help it traverse difficult terrain and allow smooth track movement.

### Steel plating

Heavy, riveted steel plates provided protection from small arms fire; however, their significant weight adversely affected the Mark I's performance.



### Trailing wheel

The trailing wheel aided in steering the Mark I; however, it proved impractical on the battlefield and was later discarded.

**1916**

## Mark I

The first tank ended the stalemate of trench warfare

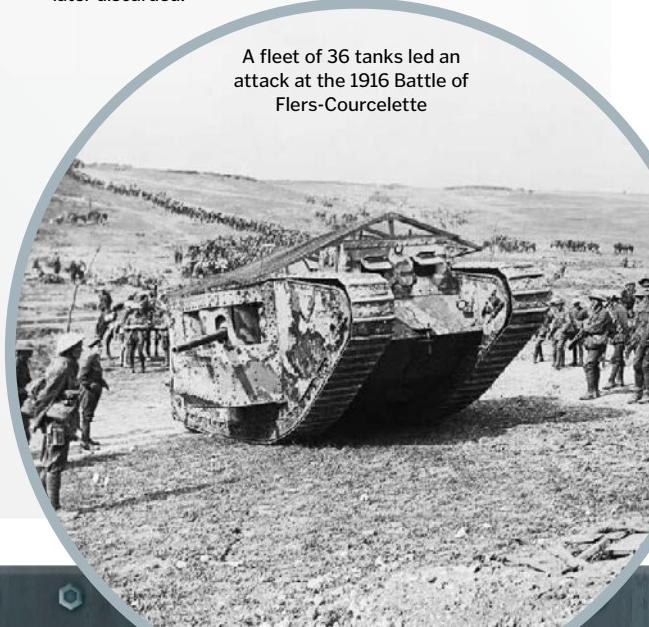
Hopes of breaking the agonising stalemate of trench warfare during World War I led to the accelerated development of the world's first operational tank, the British Mark I. The Landships Committee was established in 1915 by Winston Churchill – First Lord of the Admiralty at the time – to produce an armoured vehicle for the battlefield. The Mark I was the production model of earlier prototypes Little Willie and Mother.

The Mark I weighed just over 28 tons and was powered by a six-cylinder Foster-Daimler engine.

It was produced in two variants, the Male mounting two Hotchkiss six-pounder guns and the Female mounting two Vickers machine guns, with both variants sporting an additional three light machine guns.

Eight crewmen shared a common compartment. The British Army placed the first order for 100 Mark I tanks in February 1916, and the tank made its combat debut during the Battle of the Somme. Although several tanks broke down or became stranded, a new era in modern warfare had begun.

A fleet of 36 tanks led an attack at the 1916 Battle of Flers-Courcelette



tanks were heavy and unwieldy contraptions that were prone to mechanical failures. The engines were simply inadequate for propelling the tremendous weight of the vehicle forward. The exhaust fumes from straining engines sometimes even sickened the crews so seriously that they could not function.

The second generation of armoured vehicles reflected the experience of the Great War, and numerous innovations of the interwar years were put to use during World War II. The

purpose-built tank chassis was refined, diesel and gasoline engines became more powerful and some were borrowed from the aircraft industry. The rotating turret-mounted machine guns and cannons were introduced and armour protection improved, while communication between tanks was vastly enhanced with reliable radios that replaced hand signals and directional flags.

During the second half of the 20th century and beyond, evolving technology has transformed

the tank into a modern marvel of mechanised warfare. Global Positioning Systems (GPS) foster unprecedented coordination of units, while sophisticated infrared target acquisition and stabilisation equipment allow tanks to track multiple targets simultaneously and accurately fire weapons on the move. They also feature state-of-the-art turbine engines combined with composite armour – lighter and many times stronger than steel – for unprecedented speed and security.

Conditions inside a Mark I  
were hot, noisy and dangerous  
for the eight-man crew



An American crew awaits orders for a light tank in Coburg, Germany in 1945

M4 Sherman tanks equipped with flame-throwers were deployed by the US in the Battle of Iwo Jima in 1945



© WIKI Getty

The first tanks were designed to break through barbed wire on enemy lines





## PRESENT DAY

## Challenger 2

Considered by many military analysts to be the finest main battle tank in the world today, the development of the British Challenger 2 occurred during a five-year period from 1986 to 1991. Although it shares a common name with its predecessor, the Challenger 1, less than five per cent of the components are compatible.

Designed as a battlefield supremacy tank, the Challenger 2 weighs just under 70 tons and is the first British tank since World War II to be designed, developed, and put into production by a single principal defence contractor, the Land

Systems Division of BAE Systems. The main weapon of the Challenger 2 is the 120mm L30 CHARM (CHallenger main ARMament) rifled gun, and control of the turret and gun are maintained through solid-state electronics.

The tank is also equipped with smaller weapons, including a coaxial L94A1 7.62mm chain gun and a 7.62mm L37A2 commander's machine gun. Protected by second generation Chobham composite armour, the Challenger 2 has compiled an impressive combat record, primarily during Operation Iraqi Freedom.

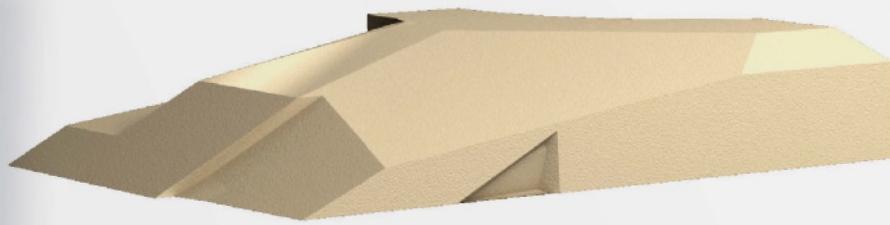


### Target acquisition

The commander and gunner of the Challenger 2 utilise gyrostabilised, fully panoramic gunsights with thermal imaging and laser range finding.



The British Challenger 2 was produced from 1993 to 2002, and approximately 450 units were completed



### Driver position

One of four Challenger 2 crewmen, the driver sits at the front and uses the periscope and night vision to steer the tank.



The Japanese Type 90 tank delivers 1,500 horsepower, as much as the Bugatti Chiron, the fastest car in the world

### Main armament

The main weapon of the Challenger 2 is the 120mm L30 rifled cannon equipped with a thermal sleeve to prevent warping.

### Suspension

A hydro-gas variable spring rate suspension provides stability for the Challenger 2 in cross-country action or on the road.

### Tracks

Tension in the Challenger 2's tracks can be hydraulically adjusted from the driver's compartment, to provide excellent mobility on various terrains.



*"Technology has transformed the tank into a modern marvel of warfare"*

DID YOU KNOW? Each AMX-56 Leclerc tank costs £8mn to build

### Secondary armament

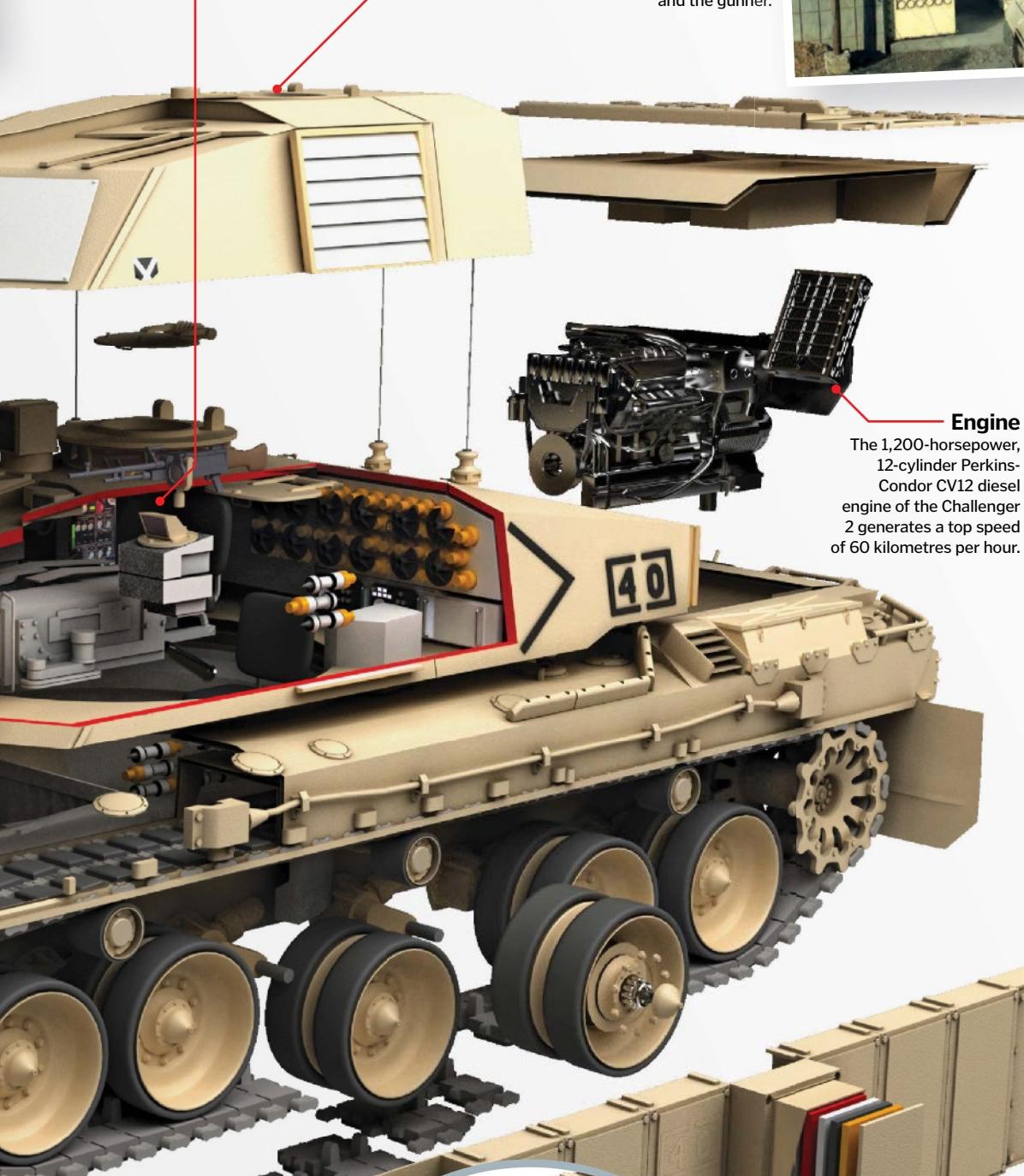
A pair of 7.62mm machine guns mounted at the loader's hatch provide close defence for the Challenger 2.

### Turret

The aerodynamic Challenger 2 turret houses sophisticated vision, target acquisition and defensive systems, along with seating for the commander and the gunner.



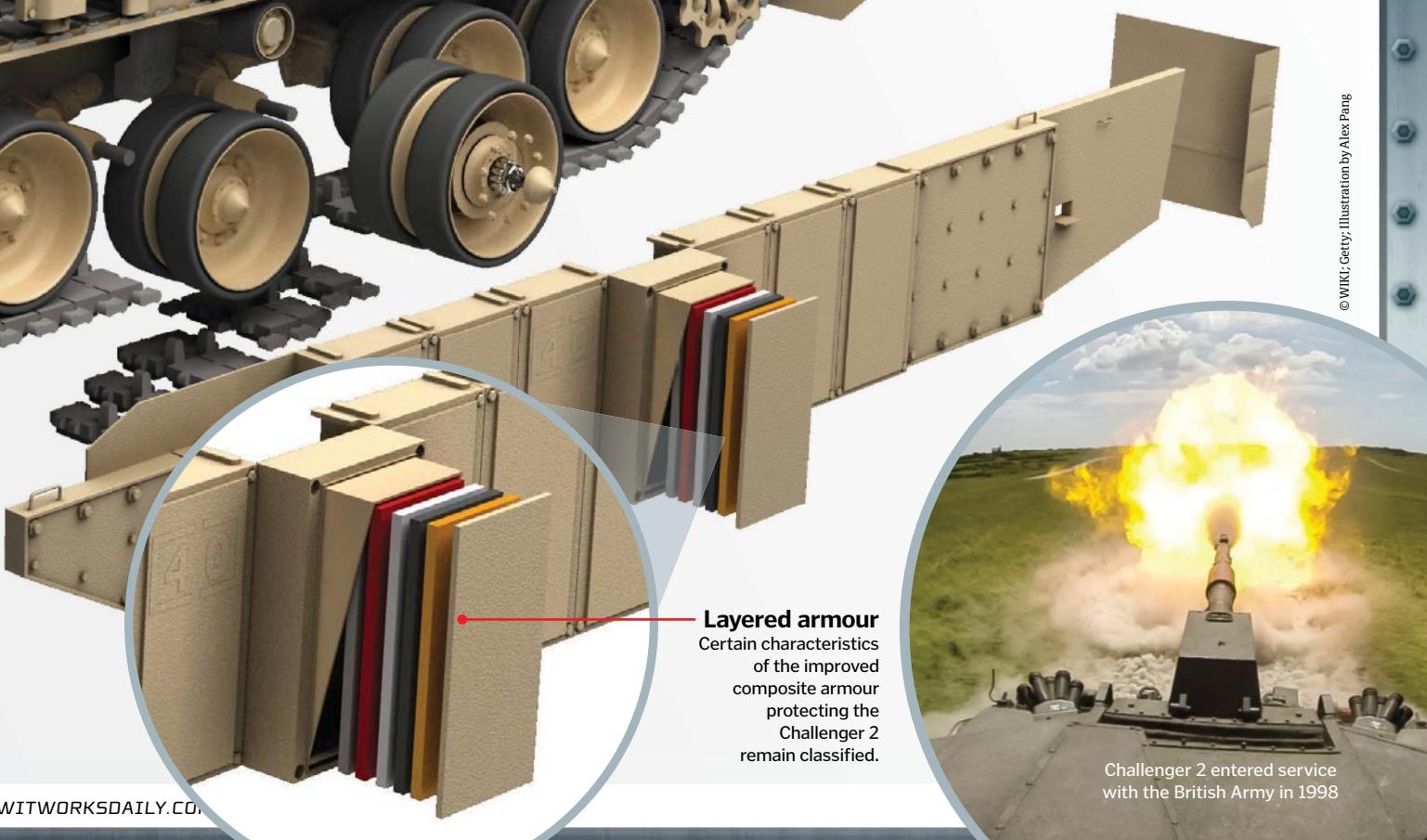
The M1 Abrams has served in the Cold War, Iraq and Afghanistan and is predicted to be in use until 2050



In 2007, Canada borrowed 20 Leopard C2 tanks from Germany to aid their troops in Afghanistan



Despite their high-tech defences, modern tanks can still succumb to enemy fire



Challenger 2 entered service with the British Army in 1998



# THE MODERN BATTLEFIELD

## From defence to attack, discover the many roles of tanks in warfare

Since their first deployment, tanks have had multiple combat roles. As the world's foremost military organisations began to evaluate the potential of the tank and either embrace or discount its future, military establishments developed their own specific roles for the armoured vehicle.

A division of labour emerged. Tanks were either built with heavy armour and weapons for striking power, or slimmed down for speed and rapid manoeuvre. Even during its infancy, the British Tank Corps fielded heavier Mark IV and Mark V tanks in World War I along with the faster and more manoeuvrable Whippet. The heavier tanks were intended to breach German trenches, creating gaps through which the lighter tanks would slash into enemy areas.

While the heavy tanks struck powerful blows, the light tanks served as modern, armoured cavalry. This tactic continued into World War II, with advanced light, medium, and heavy tanks assuming the roles of their predecessors. Tank versus tank combat became more common, and the growing diversity of operational roles resulted in a variety of armoured vehicles, some designed specifically to destroy enemy tanks.

During the Cold War and into the 21st century, cost concerns and improved technology have fuelled the concept of the main battle tank. With highly efficient engines that deliver substantial power and light composite armour that allows

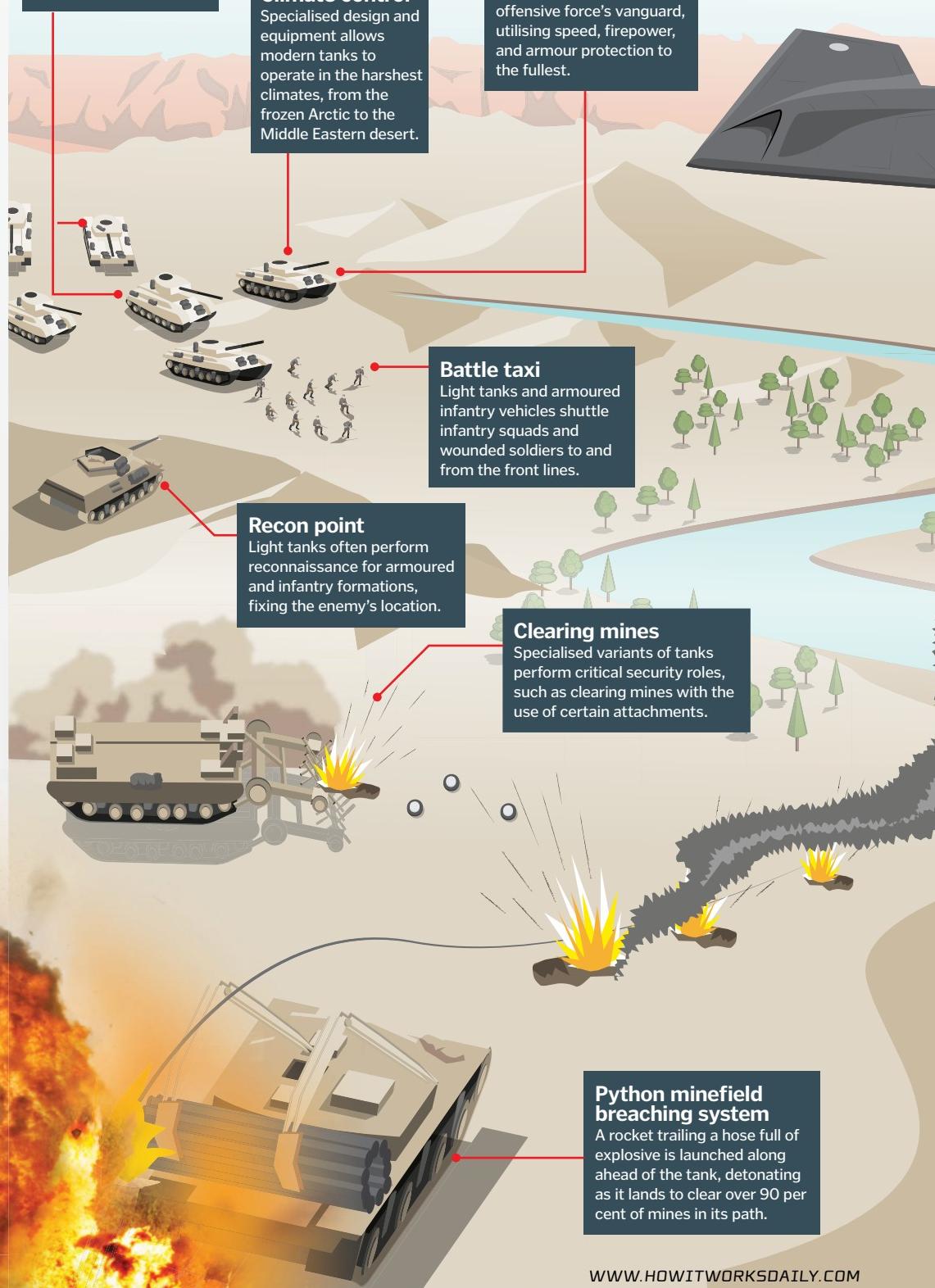
greater speed, the performance gap that previously existed has narrowed. The modern battle tank combines earlier designs into a single, lethal machine.

The German Tiger tank could destroy an enemy vehicle from 2km away



### Mutual support

In open country, tanks advance in echelon, wedge, vee, column, and other formations, covering one another to the front, sides and rear.



# TANK ROLES IN BATTLE

"Some vehicles were designed specifically to destroy enemy tanks"

## Command tank

The commander of a tank formation exerts control on the battlefield, coordinating their unit.

Lying hull down in a prepared revetment, this tank can engage the enemy while protected



## Tank vs tank

Tanks encounter their enemy counterparts in battle and fire heavy rounds specifically designed to penetrate the opposing vehicle's armour.

## Anti-aircraft defence

With heavy machine guns, main battle tanks are capable of defending themselves against low-flying aircraft and drones.

## Defence mechanism

To defeat enemy attack, tanks are armed with machine guns and grenade launchers to make smoke or dispense countermeasures.

## Mobile artillery

Tanks serve as mobile artillery, their big guns sighting distant targets and firing on enemy positions.

## Gaining traction

The large surface area of the tracks spreads the weight of the vehicle and enables it to conquer any terrain.

## Bridgelayer

Rather than a turret, some tank variants carry bridging equipment, hydraulically extended from the chassis across a waterway or other barrier.

## Amphibious capability

The tracks of these beach-storming behemoths act like paddles to wade through water.



# THE FUTURE OF ARMoured WARFARE

## The tank continues to evolve thanks to advancing technology

Grinding and blasting their way through enemy defences, tanks became icons of warfare in the 20th century. Tomorrow may be a different story. Some analysts see the armoured titans as past their golden age, while others regard them as battlefield powerhouses, evolving and adapting.

Technology continues to influence the tank and the weapons designed to counter it. An armed Apache helicopter laden with Hellfire missiles can lock onto its target and blow an enemy tank to pieces in seconds. Pilotless aerial drones can do the same. Even with technology aside, soldiers

can destroy tanks by pointing a shoulder-held weapon toward the vehicle, firing the projectile, and quickly retiring to safety.

Meanwhile, technological innovation has given tanks a renewed competitive edge in fighting insurgents in narrow streets or taking on enemy armour in the expanse of the desert. Powerful weapons and a variety of specialised ammunition make any target vulnerable to tank fire, while composite armour protects tanks like never before. Countermeasures can jam and confuse any incoming 'smart' weapons.

Unlike the heavy monsters that lumbered over No Man's Land and spouted fire and flame, the tank of tomorrow will be a revolutionary combat system. Stealth technology will veil against radar and thermal imaging, while unmanned drone tanks will power forward without risk to their operators. Articulated robotic systems like the Cheetah, currently being evaluated by the US Department of Defense, are in development. Cutting-edge technology will keep the tank powering ahead for years to come.

### THE FUTURE

#### The 'Swiss Army knife' vehicle

BAE Systems has unveiled the Terrier – a combat vehicle that looks more like a Transformer than a tank. Likened to a Swiss Army knife, it can probe for buried explosives, withstand waves of up to two metres and smash through solid concrete. This is the mechanised monster of the future.

A double-skinned floor guards against mines and the steel hull protects the two-man crew from small arm fires and shell splinters. The Terrier can also be operated by remote control up to 1,000

metres away, and can be transported by colossal military transport aircraft. This is despite weighing around 30 tons – more than six African elephants!

It's equipped with a bucket attachment that displaces obstacles and lifts heavy material, an excavator arm for moving earth, and a ripper designed to break up road surfaces and cut off the enemy. The Terrier also boasts electric smoke grenade launchers that give 360-degree coverage, and a general-purpose machine gun for defence.

### BAE Terrier

The upgrades and engineering behind the British Army's best combat vehicle yet

#### Airmobile

The 30-ton Terrier armoured vehicle is air transportable by C-17 Globemaster III or Airbus A400M aircraft.

#### Command and steering

The interior of the Terrier includes visual positioning and systems status displays. The vehicle is steered with a joystick.

#### Cameras

Cameras provide Terrier crewmen with 360-degree vision both during the day and at night with thermal imaging.



#### Remote control

The Terrier may be controlled remotely from a distance of one kilometre.

#### Amphibian

The Terrier can traverse deep water and withstand waves over two metres high.

#### Active defence

The Terrier features armour protection and mounts nuclear, biological, and chemical weapons defences, smoke dischargers, and a machine gun.



### Earth mover

The Terrier's front loader can lift several tons of material and displace earth to dig emplacements.

The BAE Terrier light armoured vehicle is being marketed to the armed forces of numerous nations



The PL-01 stealth tank utilises BAE Systems' Adaptiv technology, where each plate can be heated or cooled to create different infrared silhouettes



### Road ripper

The excavator arm features ripper and rock hammer equipment that render roads impassable, by smashing through rock and concrete.

## Stealth tanks

First introduced with naval warships, stealth technology has the potential to revitalise the next generation of armoured vehicles. The Polish Research and Development Center for Mechanical Appliances and the UK's BAE Systems are partnering to develop the PL-01 armoured fighting vehicle.

The PL-01 tank mounts a 105mm or 120mm main gun and is operated by a three-man crew. Its stealth technology includes an exterior of temperature-controlled 'wafers' that reduce the vehicle's infrared signature. The wafers also function as pixels, allowing the tank to mimic its surroundings in an innovative camouflage scheme. This means it could totally transform its appearance by matching the temperature of its surroundings and displaying preprogrammed images on the wafers.

© BAE

## The benefits of hybrid tanks

The average soldier requires about 80 litres of fuel per day for transportation and movement of supporting material. Fuel efficiency is a key element in future military contingency planning, and the hybrid tank is one viable solution. After years of development, BAE Systems and Northrop Grumman have revealed their Ground Combat Vehicle (GCV), which operates with a hybrid electric drive, providing up to 20 per cent greater fuel efficiency than earlier armoured vehicles. The GCV carries a crew of three and a squad of nine combat-loaded infantrymen protected by a core steel hull. Its significant weight, however, remains a challenge.

### Mine clearing

The Python rocket-propelled explosive system is effective in clearing mines and improvised explosive devices up ahead.



#### FUEL ECONOMY

Hybrid technology could save millions of litres of fuel during lengthy ground deployments.



#### MAINTENANCE EASE

Hybrid tanks have fewer mechanical parts, which can significantly reduce their operational costs.



#### COST-EFFICIENT

Using a hybrid electric engine can reduce fuel costs by as much as 20 per cent.



#### SPEED

Hybrid tanks can reach top speeds of 69km/h and can accelerate from 0 to 32km/h in just eight seconds.



#### PROTECTION

Varied armour packages and reinforced floors protect the personnel inside from explosives and small arms fire.



#### REDUCED NOISE

Hybrid tank powertrains are quieter, which is advantageous during stealth operations.



**5 Florida Straits**

This waterway provides access to the Gulf of Mexico for US cargo and oil tankers.

**1 Dover strait**

This is the busiest seaway in the world, serving over 500 ships per day.

**The busiest shipping lanes**
**2 Panama Canal**

This 77-kilometre long canal, with locks at each end, connects the Atlantic and Pacific Oceans.

**4 Strait of Magellan**

This strait allows ships rounding South America to avoid the treacherous waters of Cape Horn.

**3 Strait of Hormuz**

One third of all the world's oil transported by sea passes through this strait.

# Shipping lanes

90 per cent of the world's goods are transported by sea, so how is the traffic managed?

**I**t is estimated that in 2007, retail giant Walmart imported an average of one shipping container to the US from China every minute. That year alone, over 4,500 ships carried 18 million shipping containers between the world's ports. These ships are all concerned with reaching their destination in the shortest time and with the lowest fuel costs, so certain routes can get extremely crowded.

In the English Channel there is a contraflow system, which means that ships travelling south use the English side of the channel and northbound traffic uses the French side. This is enforced by the Dover Strait TSS, a radar-controlled traffic separation scheme operated by the International Maritime Organisation.

Sea lanes began with the trade routes used by sailing ships that exploited the prevailing winds

across the oceans. Although modern cargo ships use engines, today's sea lanes mostly follow the same routes because rough seas can still cause expensive delays. Close to the shore, shipping lanes are routed to ensure there is enough depth of water for the huge cargo vessels. Smaller, more manoeuvrable boats normally keep out of shipping lanes to reduce the risk of collision with these commercial leviathans.

## Engineless aircraft How this glider plans to soar to the edge of space

**G**liders can soar without engines because of currents of air around the plane that are rising faster than the glider is sinking. A good source of these updrafts is when wind strikes the side of a tall mountain. This creates a standing wave that ripples across the mountain range, and gliders are able to hang in this rising current almost indefinitely.

Mountain waves don't normally extend above ten kilometres because winds can't cross the boundary between the troposphere (the lowest layer of Earth's atmosphere) and the stratosphere – the edge of space. But there are a few places in the world where this rule is broken. In the far south of Patagonia, in Argentina, updrafts from the Andes combine in late summer and early autumn

with high altitude winds, forming a jet stream known as the polar night jet.

This year, the Perlan 2, a non-profit research aircraft currently funded by Airbus, will ride this wave to soar to heights of over

27 kilometres. At that altitude it will be above 98 per cent of the Earth's atmosphere, and it will break the altitude record for sustained flight previously set by the SR-71 Blackbird spy plane.

The Perlan 2 has a 25.6m wingspan, but weighs just 500kg – less than seven people



# The art of car aerodynamics

How the shape of a vehicle can help it slip through the air

**T**hink of a car from the 1980s and you will probably picture something similar to a box on wheels. Today's cars look far more streamlined, mostly thanks to companies factoring aerodynamics into their designs.

As a car moves through the air it pushes aside air molecules, which creates a resistant force called drag. The faster a car travels, the greater the drag becomes, meaning the car's engine has to work even harder to maintain speed. This uses more fuel, making the drive both costly and less

efficient. As car speeds have increased, it has become more important for drag to be kept to a minimum – that's where aerodynamics come into play. A more streamlined shape reduces the drag from air moving past, making it a crucial part of a modern-day car's armoury – particularly for those models with a penchant for performance.

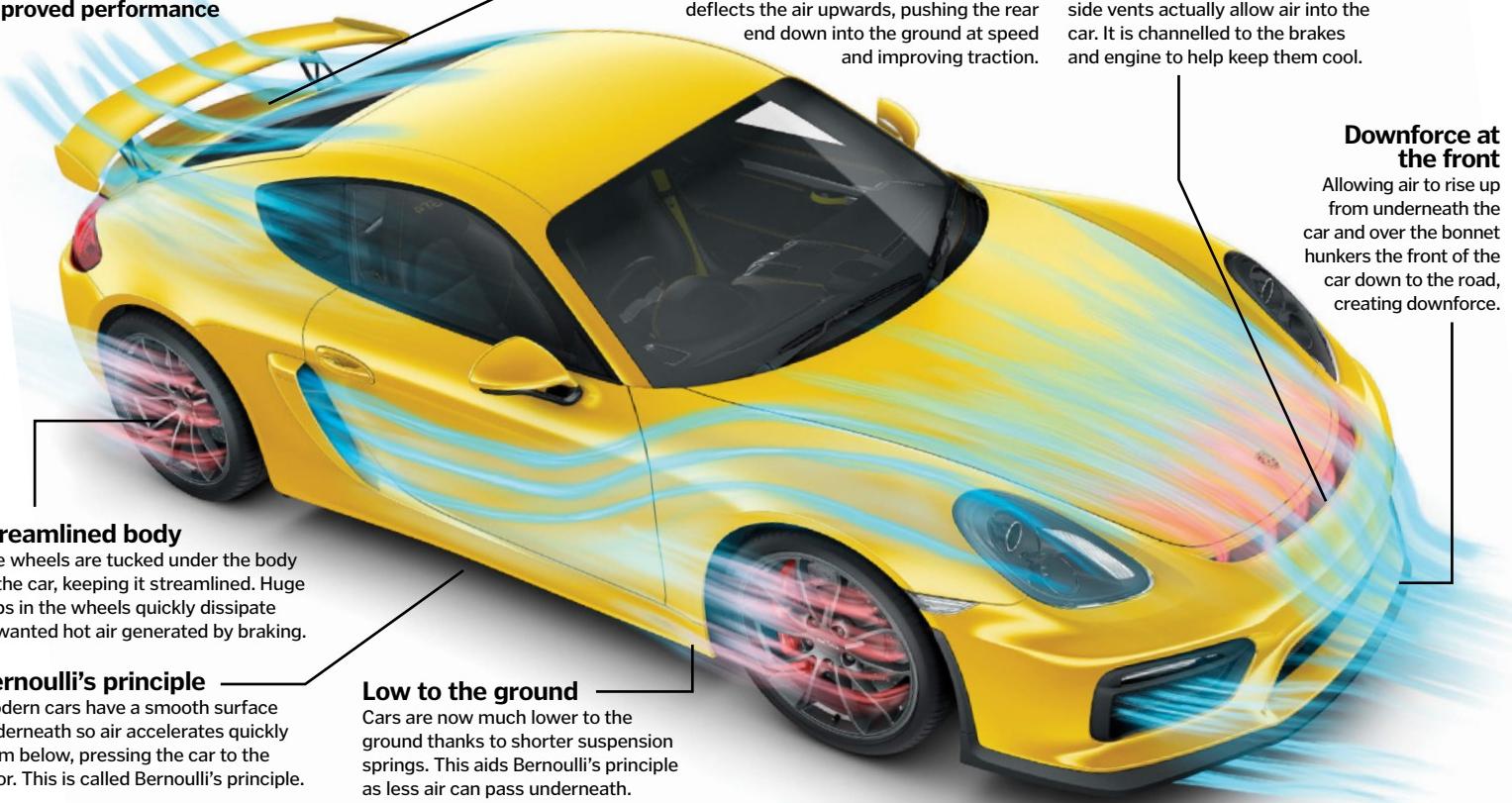
Ensuring a car has good aerodynamics means giving it a more chiselled appearance from the front, reducing its surface area that will come into contact with the air. It'll be lower to the ground

with less protruding body parts, while the rear will have more of a tapered look to reduce its slipstream.

On a road car, the rewards of good aerodynamics are actually three-fold. Enhancing the flow of air around a car not only reduces drag, making it more economical, but also allows it to slip through the atmosphere quicker, making it faster. Airflow is also utilised to keep key parts of the car cool, such as the engine and brakes, to maintain its performance even under sustained heavy use.

## Using airflow to go faster

How a sports car is designed for improved performance



The aerodynamics of a Formula One car are far more complex than those of a road car

## Extreme aerodynamics

Just like on road-going cars, aerodynamics are important on race cars too – but for different reasons. Whereas a road car uses aerodynamics mostly to reduce drag, a race car needs aerodynamics primarily to improve its downforce, which presses the car into the ground while it is moving. This improves the car's stability and helps the driver to corner faster, reducing those all-important lap times.

Race cars are not restricted by the same safety regulations as road cars so their aerodynamic setup is more extreme, with large rear wings and deep front spoilers typically positioned at either end of a smooth, slimline and hunched-down body. These flamboyant designs certainly have the desired effect; downforce on a Formula One car, for example, is so great that theoretically it could drive upside down and stay glued to the ceiling!



# HOW TO LIVE BEYOND 100

ANTI-AGEING  
RESEARCHERS ARE  
GETTING READY TO  
PUSH THE LIMITS OF  
HUMAN LIFE

024 | How It Works

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**W**e are born, we live, we age and we die. This is the natural cycle of human existence, yet some people live longer than others. The world record holder for the longest human life is Jeanne Louise Calment of France, who lived to a magnificent 122 years and 164 days. But what is the secret to a long life?

Human beings are complex, and we live for a very long time, making studies of the process of ageing a serious challenge. Most of the research to date has therefore been done in animals. Two of the favourite species for these kinds of studies are *Caenorhabditis elegans*, a tiny worm about the size of this comma, and *Mus musculus*, the humble laboratory mouse. The worms generally live for just two or three weeks, while the mice have an upper lifespan of around three years, and both have a lot of genes that are quite similar to our own. Using these models, researchers have identified several possible candidates, including stem cells, calorie restriction, and even some drugs, that could hold off the ageing process.

Scientists across the world have been trying to find the answers for decades, and after years of careful research, there is now a wealth of knowledge just waiting to be tested in people. We spoke to Brian Kennedy, CEO of the Buck Institute for Research on Aging: "We're a non-profit medical research institute that's focused on understanding ageing. We realised when the doors opened in 1999 that ageing was the biggest risk factor behind all of the disease that we care about," he explains.

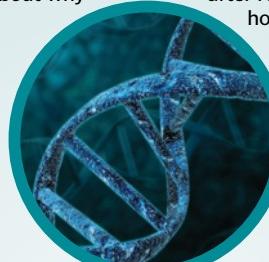
"I think the exciting thing that we have learned over the past decade is that it's really possible to slow ageing in a mouse, or even in primates. The challenge now is to take that knowledge and apply it to humans. We're not just talking about lifespan, what we really want to do is to extend healthspan: the period of time that you're disease-free and functional. The field has amassed a whole load of candidates to slow ageing, and the challenge now is to figure out how to test them."

## Do we have an age limit?

In 2010, an estimated eight per cent of the world's population were over the age of 65. By 2050, this is expected to rise to 16 per cent – that's around 1.5 billion people. But despite this seemingly phenomenal increase in human lifespan, there has actually been little change in the upper limit of human age over the last 2,000 years. Some people were living into their seventies back then, too. Brian Kennedy says: "Median life expectancy has been going up at a pretty high rate. But that's median life expectancy. The question of whether we can extend the maximum is still a bit open."

## Why do we age?

There is no easy answer to this question. As with almost everything else in biology, it is a combination of genetics and environment. One of the most well-established theories about why we age is that it is an accident of evolution. Charles Darwin's famous theory explains that the 'fittest' or best-adapted animals will reproduce, passing on their genes to the next generation. To get this chance, they need to be able to survive through their early years,



find a mate, and help their young to make it to adulthood. Over the course of our lifetimes, our bodies take damage and start to deteriorate, but after reproduction, it doesn't matter so much how long animals live. There is therefore much less pressure to evolve genes that extend life and reverse the damage. In fact, it might even be better in evolutionary terms to live fast and die young, if it means that you have a better chance of passing on your genes.



**Calories**  
This is one of the most established areas of research. In mice, rats and even primates, limiting food intake to the minimum requirement extends lifespan.

**Damage**  
Over time, our DNA starts to accumulate mistakes. This is due to damage from the environment as well as errors made when our cells divide.

**Stem cells**  
Stem cells can reproduce to replace cells that are damaged or worn out. As we age, they become less able to function, slowing the rate of repair.



## What makes us age?

There are several different factors thought to contribute to the ageing process



**Inflammation**  
Chronic inflammation is found in many age-related diseases, even when there is no infection to fight, but the relationship with aging is unclear.

**Telomeres**

The ends of our chromosomes are capped with stretches of protective DNA called telomeres. Every time a cell divides, part of this cap is lost.

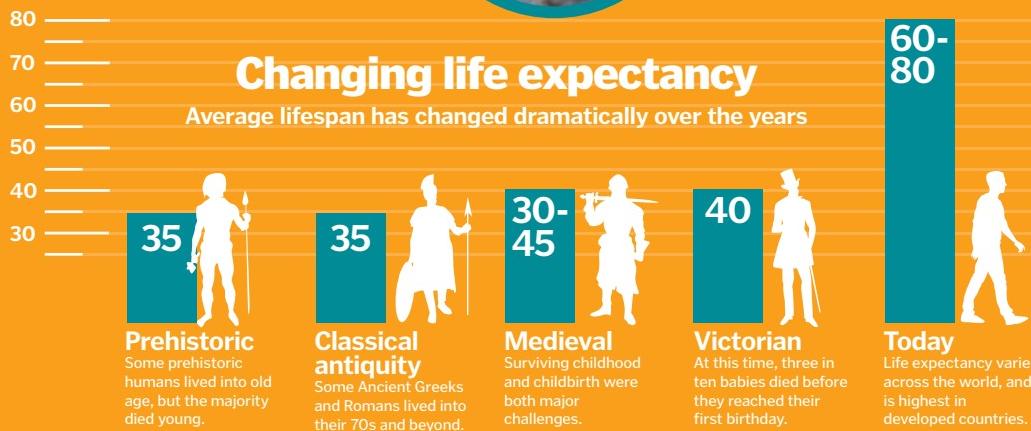
**Glycation**

Molecules called 'advanced glycation end products', or AGEs, form in our bodies over time. They have been implicated in several age-related diseases.



## Changing life expectancy

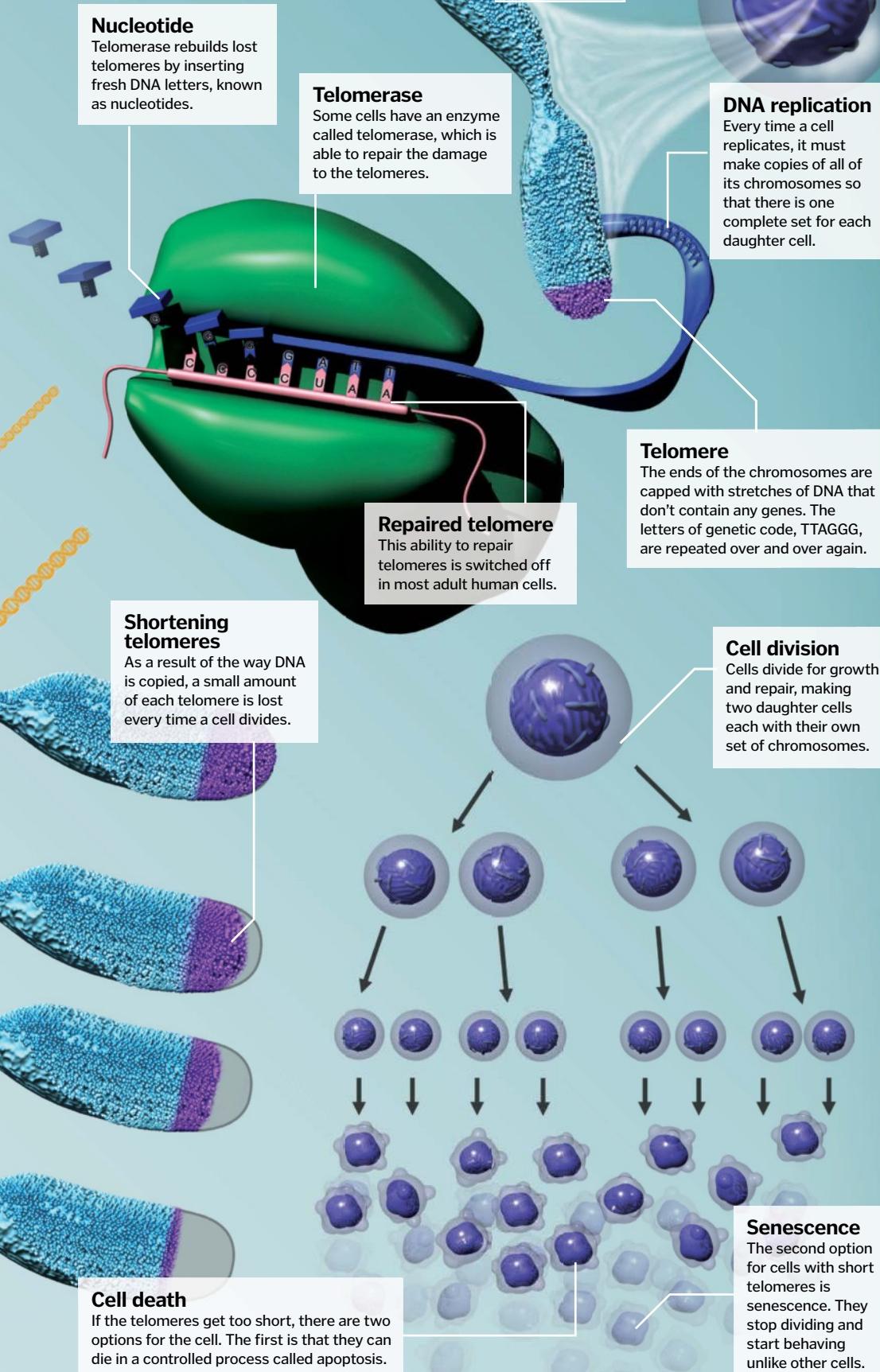
Average lifespan has changed dramatically over the years





## Telomere theory

Are the little protective caps on the ends of our DNA the secret to ageing?



# Slowing the body clock

The latest research aims to put the brakes on ageing and extend healthy years of life

Almost all of our cells have 23 pairs of chromosomes. Each chromosome contains a long molecule of DNA, wound around a series of proteins to form an X-shape, and the ends are capped with structures known as telomeres. These have been a focus for anti-ageing researchers for many years because every time a cell divides, they get a little bit shorter. Eventually, the telomere is so small that the cell can no longer go on dividing.

As Professor Kennedy explains, "If you take cells out of the body and grow them in the test tube, it was found out many years ago that eventually they stop growing. People have thought for 50 years now that this may be a component of ageing." Telomeres can be lengthened again by an enzyme called telomerase, which is found in some stem cells. However, in most adult cells, telomerase is switched off. Without it, telomeres gradually get shorter as we get older, and our cells start to shut down. Some of these older cells die, while others just stop dividing and become 'senescent', which literally means 'to grow old'.

Researchers at the Buck Institute are very interested in senescence. "One of our investigators, Judy Campisi, has been developing strategies to get rid of senescent cells in the body," he continues. "The problem has always been that there aren't that many senescent cells in the body, even in older people. It might be five per cent of the tissue, ten per cent of the tissue." So the argument was always, 'How can that have that big of an effect if it's only a small proportion of the tissue?' What Judy has found is that these senescent cells secrete factors that have bad effects on the cells in their environment."

Dr Campisi focused first on investigating the process in mice, and has developed a way to kill the senescent cells using genetic engineering. "When you do that, the animals stay healthy longer," Kennedy explains. Dr Campisi is now working on finding a drug that can produce the same results. But the aim isn't necessarily to extend life. These senescent cells could be contributing to age-related diseases, and that's the real focus for the researchers. "Our goal is to keep people healthy and functional longer. They will probably live longer too, but it's really about healthspan more than lifespan".

## Anti-ageing pills

A pill to slow the ageing process might sound inconceivable, but there are actually a few candidate drugs already. Two of the most publicised are rapamycin and metformin. It has been known for a long time that restricting calorie intake can extend the lifespan of mice, and researchers have pinpointed genes involved in a nutrient-sensing pathway called 'target-of-rapamycin' (TOR). When cells have lots of nutrients, this pathway promotes growth, but when nutrients are scarce, it switches the cell over to recycling its own molecules. This switch seems to be critical.

Rapamycin is a drug already used in people to prevent the rejection of transplanted organs, and it dampens the activity of the TOR pathway, helping cells to switch into recycling mode. Rapamycin

slows ageing in worms, flies and in mice, but the effects on humans aren't yet known.

An alternative anti-ageing candidate is metformin. This drug decreases the amount of glucose made by the liver and increases uptake of glucose from the blood, and is already used to treat diabetes. Evidence in worms and some mice shows that metformin can increase longevity, and it also seems to decrease the risk of age-related diseases in people with diabetes. It is not clear whether the drug would have any benefit in healthy people, but researchers in the United States are keen to do a clinical trial to find out.

Human studies are needed to find out whether these drugs really can slow ageing



## The future of anti-ageing

At the moment, most anti-ageing research is focused on extending human healthspan by staving off disease. But we are in the midst of a scientific revolution, and there is no telling what will be available hundreds of years from now. Already, scientists can build bionic limbs that respond to the wearer's thoughts, they're learning the incredible potential of stem cells, and they can 3D print structures for transplanting into the body. In the future, some hope that it will be possible to go beyond biology, using these kinds of advances to become 'transhuman' – living longer, and ultimately cheating death completely.

The ideas for transhumanism are limitless, and range from augmented body parts, through to genetic modification and cloning, all the way up to downloading your thoughts onto a memory stick and living forever as a machine. Unfortunately – or fortunately, depending on how you look at it – this future is still a long way off.

*"Our goal is to keep people healthy and functional longer. It's really about healthspan more than lifespan"* Brian Kennedy



### Elixir of youth

Drugs may one day be able to slow the ageing process, and help to avoid diseases like Alzheimer's or Parkinson's.



### Genetic engineering

Editing the youthfulness genes in our genome could change the way that humans age.



### Cloning

How about living again as an identical version of yourself? Cloning technology could make copies of you or your cells.



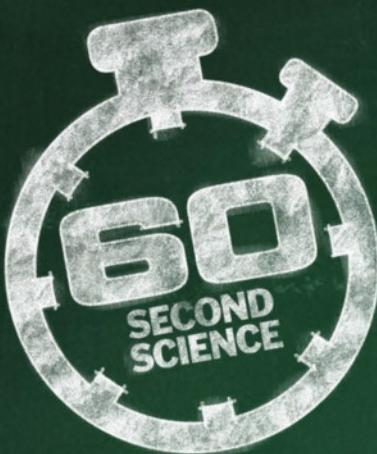
### Upgrading organs

Advanced 3D printing techniques could lead to custom-made organ replacements.



### Replacing limbs

Bionic limbs have the potential to be stronger and more durable than the real things.

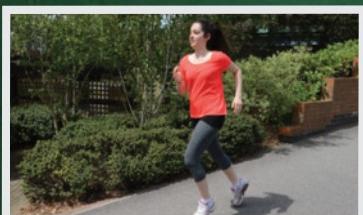


## BACKGROUND

All the cells in our body need oxygen to survive, which we get from the air we breathe. Cells use oxygen to generate energy from food and produce carbon dioxide as a waste product. Too much carbon dioxide is harmful and makes the blood acidic, so we need to get rid of it. The process of getting oxygen from the air into the body and breathing out unwanted carbon dioxide in return is known as respiration.

## IN BRIEF

Oxygen's journey into our cells starts with breathing, which is controlled by a part of the brain called the respiratory centre. It sends signals to the intercostal muscles and the diaphragm, telling them to contract, expanding the lungs and pulling air down the windpipe and into the branching tubes of the lungs. Each tube ends in balloon-like sacs called alveoli, which are surrounded by tiny blood vessels. Inhaled air is 21 per cent oxygen but there's a lower level in the bloodstream because some of it gets used up. Similarly, air contains less than 0.05 per cent carbon dioxide, but there's more in the blood. This means oxygen passes from the alveoli into the blood – through the process of diffusion – while carbon dioxide moves the other way.



The burning feeling runners get in their muscles is a result of anaerobic respiration

## SUMMARY

Our cells need oxygen to generate energy, producing carbon dioxide as a waste product. Respiration describes how oxygen moves from the air into the body and unwanted carbon dioxide gets back out.

# Respiration

DISCOVER THE SCIENCE BEHIND EVERY BREATH YOU TAKE

## Breathe in, breathe out

From air to blood – how oxygen gets into the body

### Trachea (windpipe)

Lined with sturdy rings of cartilage, the trachea is the 'inlet' pipe for air coming into the lungs.

### Huge surface area

It is estimated that the total surface area inside the lungs is around 70 square metres. That's almost half a tennis court!

### Diaphragm

Controlled by signals from the brain, the diaphragm is a big sheet of muscle that expands the lungs.

### Tube network

The lungs are made up of lots of branching tubes, called bronchioles.

### Alveoli

Each bronchiole ends in balloon-like sacs called alveoli, where oxygen and carbon dioxide move in and out of the blood.

### Gas exchange

Oxygen moves from the air in the alveoli into red blood cells. Carbon dioxide goes the other way.

### Thin walls

The walls of the alveoli and blood capillaries are just one cell thick, so gases only have to move short distances.

## TWO TYPES OF RESPIRATION

WE NEED TO RESPIRE CONSTANTLY SO THAT OUR CELLS CAN GENERATE ENERGY AND POWER EVERY FUNCTION IN THE BODY. TO AVOID THERE EVER BEING A LAPSE, THERE ARE TWO TYPES OF RESPIRATION. AEROBIC RESPIRATION REQUIRES OXYGEN, PRODUCING CARBON DIOXIDE AND WATER AS WASTE PRODUCTS. AN ALTERNATIVE 'BACK-UP' PROCESS CALLED ANAEROBIC RESPIRATION

HAPPENS WHEN OXYGEN ISN'T AVAILABLE, BUT IT CREATES A CHEMICAL CALLED LACTIC ACID. IF LACTIC ACID BUILDS UP IN CELLS AND TISSUES IT CAN BE TOXIC, AND CAUSES A BURNING FEELING IN OUR MUSCLES DURING AND AFTER INTENSE EXERCISE. AS A RESULT, WE CAN'T RELY ON ANAEROBIC RESPIRATION FOR TOO LONG, EXPLAINING WHY YOU CAN'T RUN A MARATHON AT SPRINTING SPEED.



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## Will you help the snow leopard claw its way back from the brink?

**Snow leopards have survived in the Himalayas for thousands of years. But right now, there are as few as 300 left in Nepal. The harsh reality is that they're being hunted by poachers for their bones and precious fur – and they urgently need your help if they are to live on.**

By adopting a snow leopard today, you'll help protect this endangered big cat for future generations.

### Your present. Their future.

For as little as £3 a month, you or your loved one will receive an adoption pack, an adorable cuddly toy and regular updates from people on the ground working tirelessly to help save the beautiful snow leopard.

What's more, you'll have the satisfaction of knowing you're helping us to train and equip courageous anti-poaching rangers. And you'll discover what it takes – and how it feels – to help save a species.



a gorgeous snow leopard toy



an adoption pack



regular updates from the field

= **from just  
£3 a month**

**Adopt a snow leopard today by filling in the form below, visiting [wwfsnowleopard.com](http://wwfsnowleopard.com) or calling 0845 200 2392**



## Yes, I would like to adopt a snow leopard today

Please indicate how much you would like to give each month

I would like to give  £3  £5  £7  £10

My choice £  each month (min. £3)

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# The science of spirits

People have been distilling alcohol using the same basic principles for more than 1,000 years

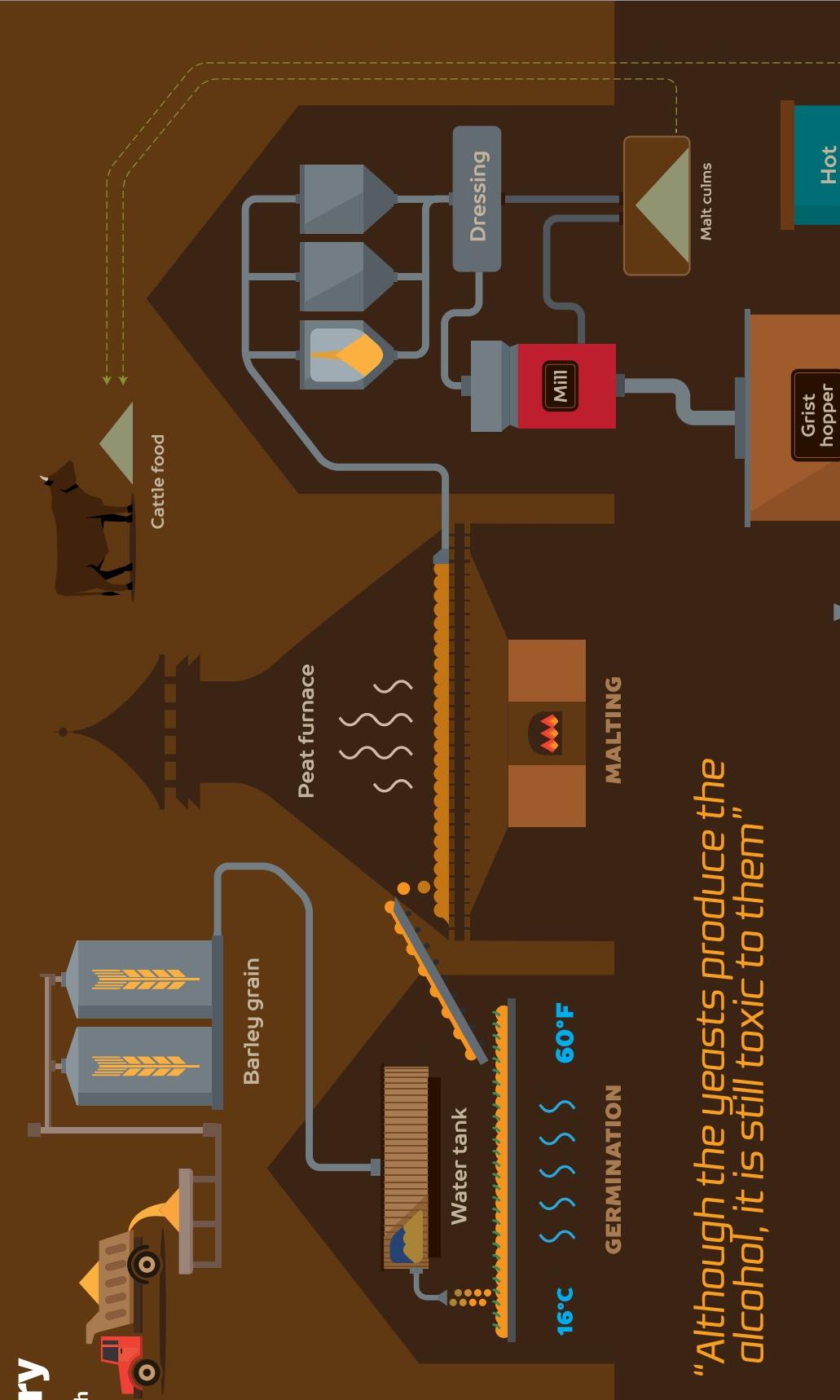
Yeast consume sugar, breaking it down into ethanol (alcohol) and carbon dioxide in a process called fermentation. People have been taking advantage of this trick to produce alcoholic drinks since prehistory, but there is a limit to how strong wine and beer can get before the yeasts start to die. Although the yeasts produce the alcohol, it is still toxic to them in large enough quantities. Making stronger alcoholic drinks requires a bit more human intervention, and this is done by the process of distillation, which involves separating one liquid from a mixture of liquids. Alcohol boils and condenses at a lower temperature than water, a property which allows the two liquids to be separated.

In a distillery, a low percentage alcoholic mixture is heated until the alcohol starts evaporating. The vapour is then siphoned away before being cooled and collected. As the alcohol evaporates first, some of the water is left behind. However, there's more to spirits than just alcohol. The yeast is used to break down complex products like wheat, barley, sugar cane, fruit, potatoes or honey, so the condensed liquid is far from pure. The extra compounds are known as congeners, and they help to give each spirit its unique taste.

Different spirits are also treated differently during the distillation process. Vodka is distilled over and over again, passing through several columns to produce the purest alcohol possible, before being watered down to reach a drinkable concentration. Gin goes through a similar process, but it is flavoured with secret mixtures of juniper berries and other botanicals. Spirits such as rum and whisky are left to age in barrels, often for years at a time. While the process is fairly simple, the exact way that spirits are made has a dramatic impact on the final flavour, and each distillery has its own secret recipes and techniques.

## The distillery

Making spirits is easy, but making good spirits is both an art and a science



### 1 Fermentation

A mixture of water, yeast and a source of sugar such as grain or potato are mixed together and allowed to ferment for around a week.

### 2 Boiling

When the mixture is roughly ten per cent alcohol, it is ready for the next stage. It is moved into the pot, which is surrounded by a double wall filled with steam.

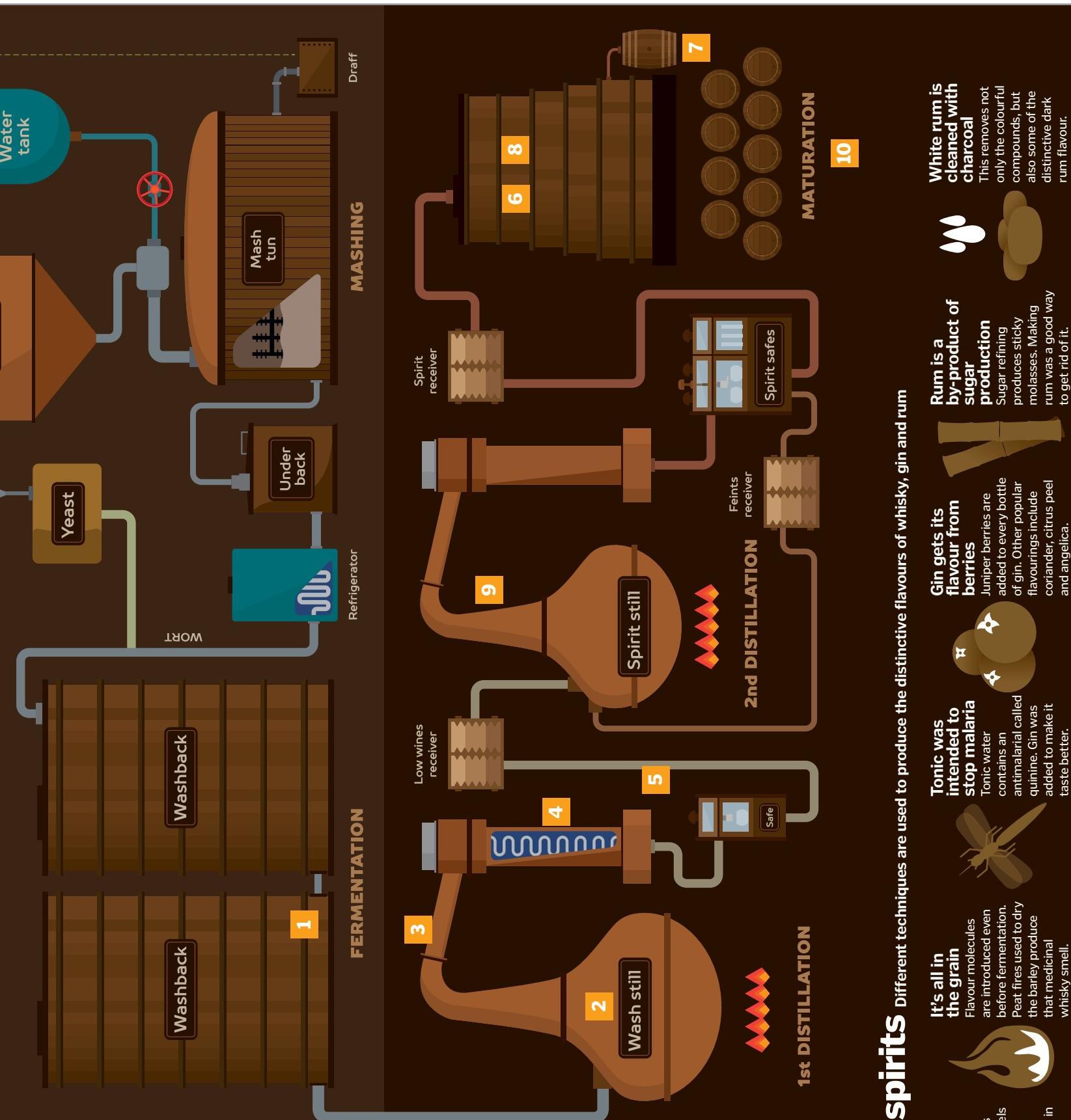
### 3 Evaporation

Alcohol has a lower boiling point than water, at around 78°C. Both alcohol and water must be turned to gases for the next phase. The evaporated alcohol and water move through the distillation column, passing over cool copper plates. As the temperature drops, water condenses first, leaving the alcohol to move up and out of the column.

### 4 Distillation

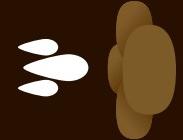
"Although the yeasts produce the alcohol, it is still toxic to them"

Hot



**Know your spirits**

**White rum is cleaned with charcoal** This removes not only the colourful compounds, but also some of the distinctive dark rum flavour.



**Rum is a by-product of sugar production**

Sugar refining produces sticky molasses. Making rum was a good way to get rid of it.



**Gin gets its flavour from berries** Juniper berries are added to every bottle of gin. Other popular flavourings include coriander, citrus peel and angelica.



**Tonic was intended to stop malaria**

Tonic water contains an antimalarial called quinine. Gin was added to make it taste better.



**t's all in  
the grain**

Flavour molecules are introduced even before fermentation. Heat fires used to dry the barley produce that medicinal whisky smell.



**Whisky**  
tastes like  
**wood**

This dark spirit is aged in oak barrels for years, and picks up flavour molecules found in the wood.





# How a bruise forms

The colour-changing contusions caused by knocks and bumps

**W**hether it's a nasty fall or an accidental encounter with the edge of a table, the evidence of your mishaps can often stay with you for weeks in the form of a bruise. These contusions of the skin are caused by blood vessels bursting beneath the surface, resulting in a colourful mark that is tender to the touch.

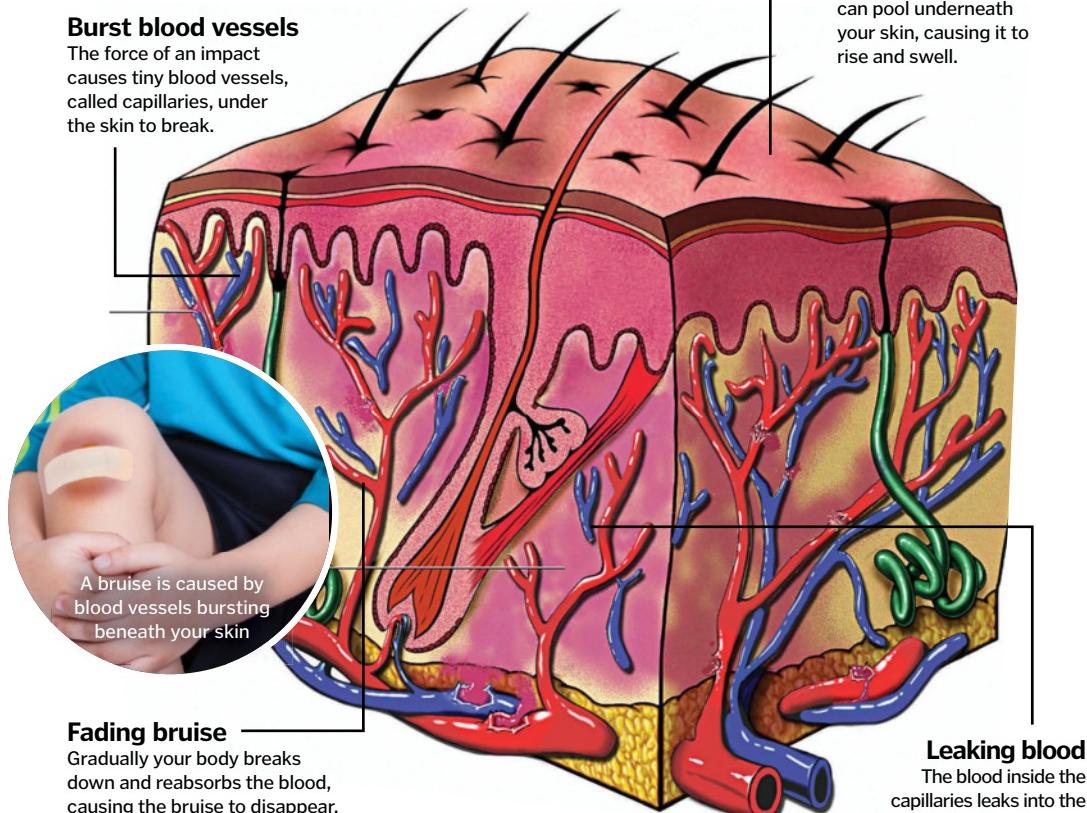
To minimise bruising after an injury, it is best to put an ice pack on the affected area. The cold will reduce blood flow to that area, limiting the amount that can leak from the blood vessels.

## Underneath the surface

How a blow to the skin can leave you bruised

### Burst blood vessels

The force of an impact causes tiny blood vessels, called capillaries, under the skin to break.

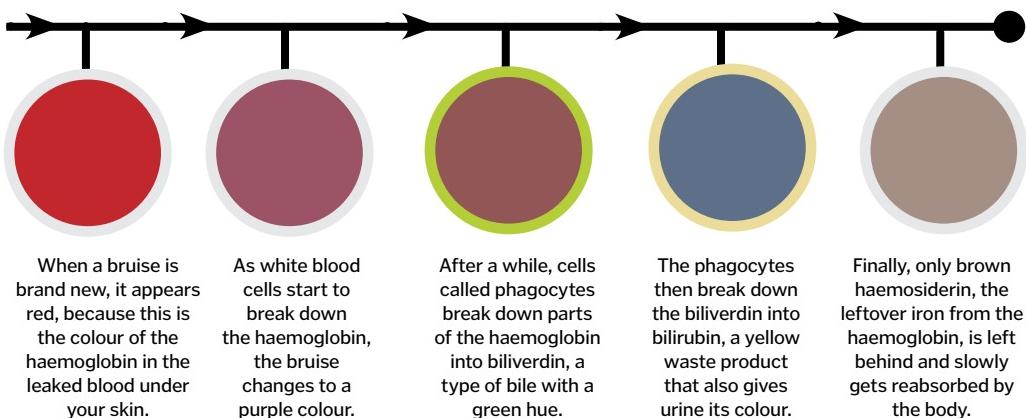


### Fading bruise

Gradually your body breaks down and reabsorbs the blood, causing the bruise to disappear.

## How a bruise heals

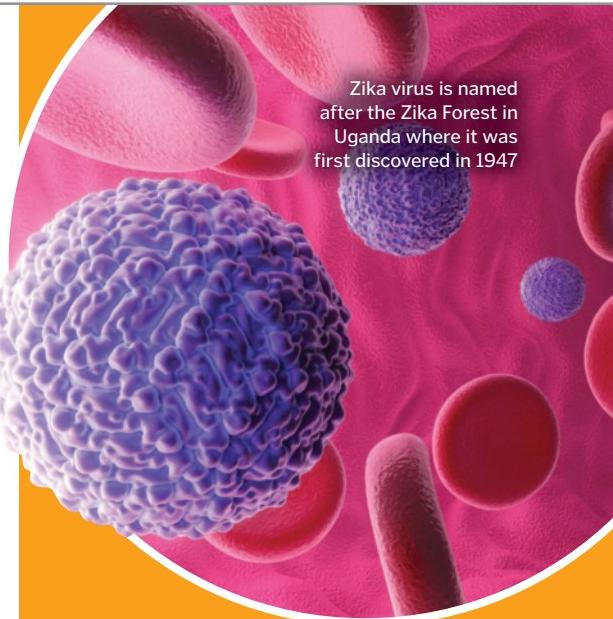
The colourful process of repair



Luckily our bodies are pretty good at repairing themselves and as a bruise starts to heal, it puts on an impressive colour-changing display. After two to three weeks of changing from red to blue, then green, yellow and finally brown, it will disappear completely.

However, if a bruise doesn't fade, then your body may have blocked off a pool of blood beneath the skin, forming what is known as a haematoma. If this happens, then the blood needs to be drained by a doctor.

Zika virus is named after the Zika Forest in Uganda where it was first discovered in 1947



## Zika virus

Discover how this mosquito-spread virus affects the cells of adults and unborn babies

**Z**ika is a ribonucleic acid (RNA) virus, meaning its genetic material is stored in strands of unstable RNA rather than the more stable DNA that most organisms use. Mutations are much more common in RNA, which makes it difficult for other organisms to develop lasting immunity to the virus. It is primarily transmitted via the bite of the Aedes mosquito, which feeds on the blood of infected individuals and deposits the virus into another person's skin via their saliva. There, it causes the skin cells to digest their own cytoplasm – the fluid that fills the cell.

Eventually this causes the cells to break up and die, so the virus can move on to repeat the process in new cells. This leads to the formation of an excess of watery fluid in the skin, one of the common symptoms of Zika fever. Other symptoms include rashes, joint pain and conjunctivitis, but are usually mild and last for up to a week. However, if a pregnant woman becomes infected, the virus can disrupt the neural stem cells that form the cerebral cortex of her unborn child's brain. Recent studies have confirmed links to microcephaly, a birth defect where the brain does not develop properly.

Zika is transmitted via the bites of female Aedes mosquitoes



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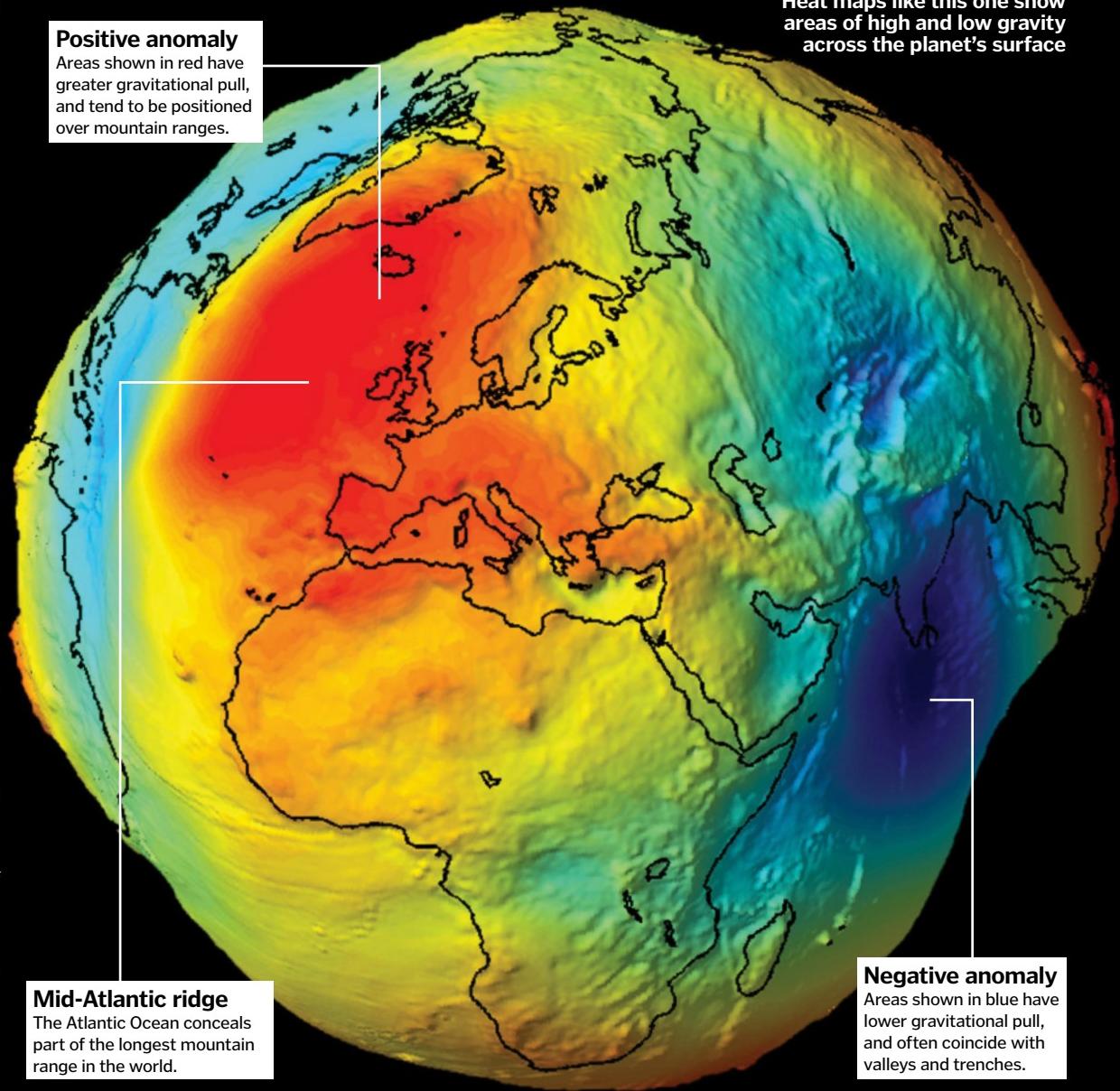
# Gravity maps

The Earth might look round, but our gravity is lumpy

If Earth were smooth like a ball, its gravitational field would be equally smooth, but you only have to look out of the window to see that our planet has lumps and bumps. It is uneven both inside and out, and this affects our gravitational pull.

Albert Einstein explained that gravity occurs because mass distorts space and time. Stars, planets, and even humans create dips in the fabric of the universe, and objects that come close will fall in to these. The more mass in a given space, the more of a dip is created, and the stronger the gravitational field.

It makes sense then, that Earth's gravity is not uniform. The planet is covered with mountain ranges, valleys and seas, and is made up of chemical elements with different atomic weights and densities. Even the movement of water in the oceans or the melting of glaciers can have an impact. All of these inconsistencies across our planet create an ever-changing map of so-called 'gravity anomalies'.



## Earth's gravity

Heat maps like this one show areas of high and low gravity across the planet's surface

# Tooth whitening

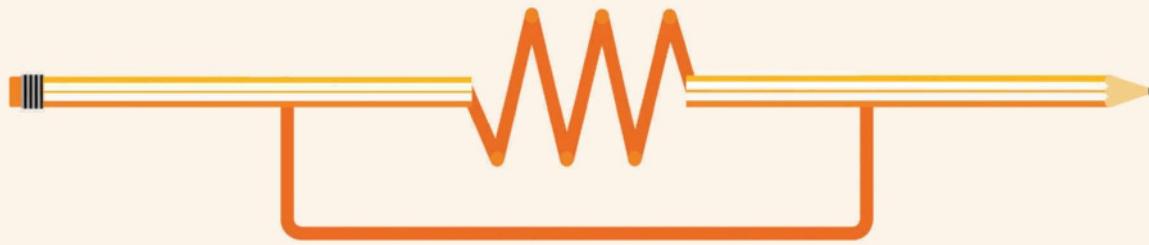
How do you get that perfect Hollywood smile?

The hard enamel outer surface of each tooth is coated in a layer called the pellicle. It is made mainly from proteins found in the saliva, but can also contain trapped particles from food, drink, and cigarette smoke. Over time, these can cause discolouration. The film can be removed by brushing, or by scraping, sonication, or chemical treatments, but if the compounds sit on the teeth for too long, the underlying enamel can also become stained. This doesn't tend to cause any harm, but it can't be removed by cleaning alone.

Dentists offer two main forms of tooth whitening: carbamide and hydrogen peroxide. They both act as bleaching agents and work to lighten the stains. The chemicals are most often applied as gels inside a specially made gum shield that is moulded to the shape of your teeth, and laser light can also be used to speed up the process. At-home treatments are also available, but the NHS advises against their use. The kits might not be strong enough to have the desired effect, and if the gum shield doesn't fit properly, the chemicals could leak and cause gum damage.



Dentists can use custom-made gum shields and controlled laser light to whiten teeth



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## Why does the chocolate flow inwards?

Learn how surface tension creates the distinctive fountain shape

### Chocolate attraction

The liquid molecules in the molten chocolate are more attracted to each other than the molecules in the surrounding air.



#### Surface tension

The liquid molecules on the surface bunch up with other liquid molecules to try and form the shape with the smallest possible surface area.

#### Flowing inwards

The surface tension causes the liquid to take up the smallest possible area, pulling it inwards as it flows.

## How do space blankets work?

Discover how wrapping yourself in foil helps regulate body temperature

Marathon runners crossing the finishing line will often be handed a shiny blanket to wrap around their shoulders, but what does this thin piece of foil actually do? Space blankets, also known as mylar blankets, were first developed by NASA to regulate the temperature inside the Skylab space station when its heat shield broke in orbit. They are made from a very thin plastic film coated with vaporised aluminium, giving them a highly reflective surface. While NASA used this to reflect heat away from Skylab and keep it cool, runners do the opposite.

As heat radiates off the wearer's body, the blanket's shiny surface reflects around 80 per cent of it back, helping to keep them warm. It also helps to slow heat loss through evaporation, which occurs when you sweat. Trapping this heat increases the humidity of the air next to the skin, preventing body temperature from dropping dangerously quickly when the person stops exercising. Finally, space blankets act as a barrier between the wearer and the wind, stopping it from lowering body temperature by convection.

Although invented for the Space Age, space blankets are also useful here on Earth

# Chocolate fountain physics

Find out what a delicious party centrepiece can teach you about fluid dynamics

As well as being a tasty treat at parties, chocolate fountains are also useful for understanding the science of how non-Newtonian fluids – fluids whose viscosity varies depending on how much force is applied to them – move. Mathematics students at University College London have even conducted a study on the topic, examining the different ways the delicious molten chocolate flows through the various stages of the machine.

First, a pump creates pressure to force the chocolate up the central pipe, then it thins out as it flows out over the domes. However, the most

interesting part concerns how the chocolate then cascades down in curtains. Instead of falling straight down into the bowl below, the chocolate pulls inwards towards the middle of the fountain.

This is similar to what happens to water, a Newtonian fluid, in a water bell, leading the students to conclude that surface tension causes the slanted flow. You can create your own water bell by fixing a coin on top of a pen and placing it vertically under a tap, sending the water flowing in a bell-shape around the pen.



# Radioactive dating

Find out how scientists measure time using clocks hidden in Earth's rocks

**M**ost chemical elements remain stable over time, but there are radioactive variants of common atoms, and these are unstable. They cannot hold themselves together, and as the years pass, they gradually decay. One of the most well-known is carbon-14, which has two extra neutrons in its nucleus ('normal' carbon, by comparison, is known as carbon-12). Atoms of carbon-14 cannot hold on to the extra neutrons forever, and over time they will lose them to form stable, non-radioactive nitrogen-14. This decay happens at a fixed rate, like the ticking of a clock, and is known as a

half-life: the time it takes for half the unstable atoms in a given mass to decay.

The carbon-14 clock allows scientists to determine the age of fossilised remains of living things. All life on Earth is carbon-based, and when animals and plants are living, they incorporate traces of naturally occurring radioactive carbon into their tissues. When they die, this process stops, and the carbon clock starts ticking. When we dig up fossils years, or even millennia later, some of this carbon will have decayed, so by measuring the amount that is left, we can tell how old the samples are.



Radioactive dating is used to tell the age of fossilised remains, like this velociraptor skull

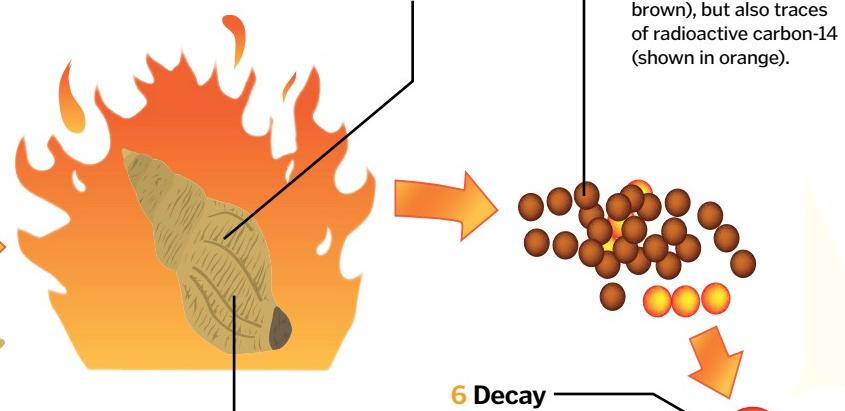
This technique only works for (formerly) living things, but there are naturally occurring radioactive versions of other elements, which are incorporated into rocks as they form. Each of these rock clocks ticks at a different rate. When magma solidifies to form igneous rocks, it traps radioactive potassium-40, which takes 1.25 billion years to tick down by half. Uranium-238 takes 4.5 billion years, thorium-232 takes 14 billion years and rubidium-87 takes 48.8 billion years.

## Carbon dating

This form of radioactive dating is used to pinpoint the age of once living things

### 2 Fossil

When living organisms die, they stop making new molecules, so no new carbon-14 is added to their remains.



### 4 Testing

To find the age of a fossil, scientists remove a small piece and burn it to release the carbon as carbon dioxide gas.

### 1 Living organism

During their lifetimes, living organisms incorporate small amounts of naturally occurring radioactive carbon-14 into their tissues.

### 3 Ticking clock

The carbon-14 already present in the fossilised organism gradually decays.

### 5 Carbon

The fossil contains mainly 'normal' carbon-12 (shown in brown), but also traces of radioactive carbon-14 (shown in orange).

### 6 Decay

The carbon-14 will continue to decay, and this can be detected by a Geiger counter.

Nitrogen

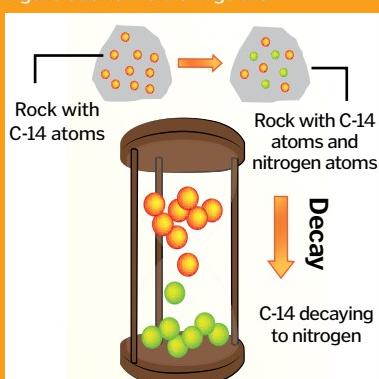
Electron

Radiation counter

## What is a half-life?

The reason that radioactive atoms can be used as clocks is because they decay at a predictable rate. However, waiting for radioactive decay is a bit like waiting for corn kernels to pop. We know approximately how long it should take for all the corn to become popcorn, but we can't predict which kernel will pop first. In the same way, we don't know exactly when radioactive clocks will tick, but we do know the time it takes for half of the atoms in a sample to decay. This is known as the 'half life', and for carbon-14, it is 5,730 years.

The half-life is not affected by things like temperature, pressure, or other environmental influences, meaning that, whatever was going on in the world at the time, these molecular clocks would continue ticking, keeping time and allowing scientists to look back and figure out how old things are.



By measuring the chemical make-up of a rock, we can tell how long the clock has been ticking



# BBQ science

It takes physics, chemistry and biology to grill a perfect burger

**W**hether your barbecue is plumbed into a gas tank, or is a more traditional coal or wood-fired burner, there are two key ingredients for a good grilling: heat and smoke.

Barbecuing is very different from cooking on a hob or in an oven. On the hob, the heat moves from ring to pan to meat mainly by conduction. The metal pan is in physical contact with the heat source, and the meat is in direct contact with the pan. Alternatively, when meat is cooked in an oven, heat mainly travels by convection. The element heats the air, which circulates around the oven, and around your food.

On a barbecue, however, the burgers and sausages are far above the coals, and with the lid off, convection isn't nearly as important as it is in the oven. Instead,

most of the heat comes from infrared radiation. Radiant heat is absorbed by dark surfaces, so lining your barbecue with shiny foil can help to direct all of the warmth to where you need it. When using coals, waiting for them to turn white with ash ensures that they are evenly heated through.

As the meat dries out on the outer edges, it starts to brown; sugar reacts with protein to create that distinctive barbecued crust. You can do this indoors on the hob too, but to get that authentic barbecue taste, you need smoke.

When fats and juices drip down on to the barbecue, they burn, releasing flavour and odour molecules that rise up, filling the air with the scent of summer, and sticking to the surface of the meat.

## Dripping

Cooking over an open heat source allows fat and other juices to drip down and combust, releasing complex flavours.

## Maillard reaction

The crispy brown colour of barbecued food is down to a reaction between the sugars and proteins in the meat.



Drips of fat create little flames, releasing flavour molecules into the air

## Barbecue tips

### 1 Wait for the coals to go white

Not only does this mean that they are hot enough, the coating of ash will help to control the amount of heat they radiate.

### 2 Preheat the grill

If you're after those charred grill lines, you need to make sure that your grill is scorching before you put your burgers on.

### 3 Don't bother searing

This technique is often thought to seal in the meat's juices, but may actually do the opposite.

### 4 Turn frequently

No one likes a burnt sausage. Keep them moving to prevent one side heating up too much.

### 5 Let it rest

This allows the muscle fibres to relax a little, holding on to more water when the meat is cut.

## Anatomy of a barbecue

The secret behind the mouth-watering taste

### Rising smoke

The intense heat of the barbecue warms the air. It expands and rises upwards, carrying soot, water and delicious smells.

### Temperature test

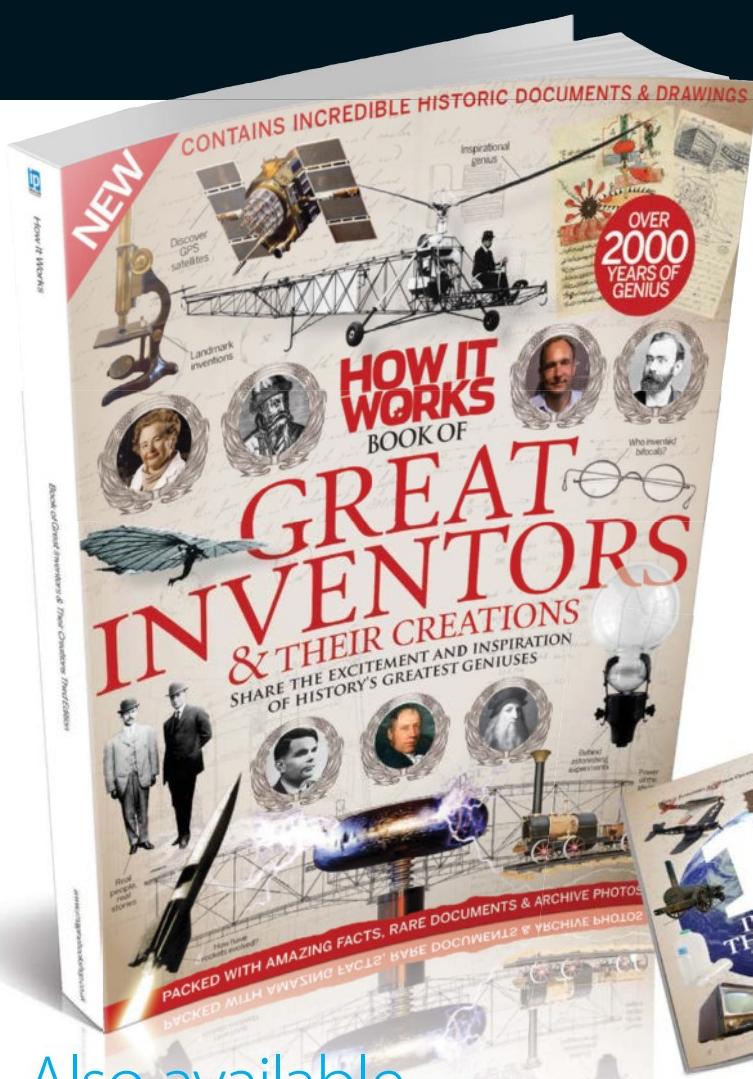
White coals with a deep red glow are very hot. When they start to turn yellow-brown, they are beginning to cool.

### Airflow

Let more air in to stoke the fire, or cut off the supply to cool it down.



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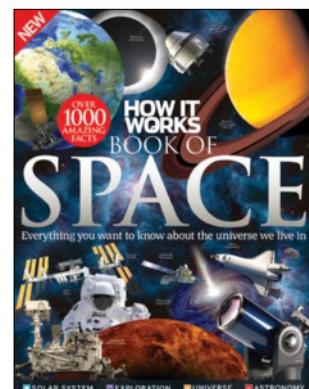
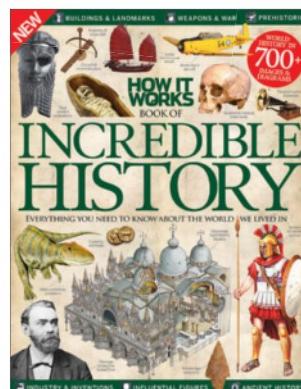
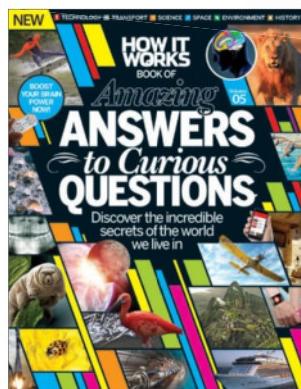
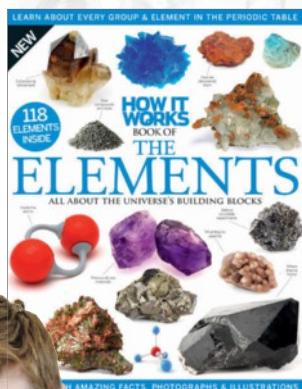
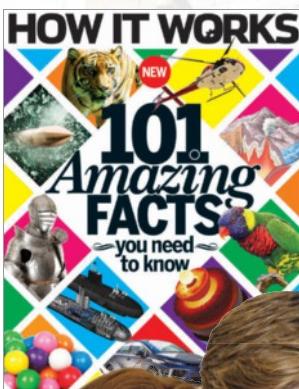


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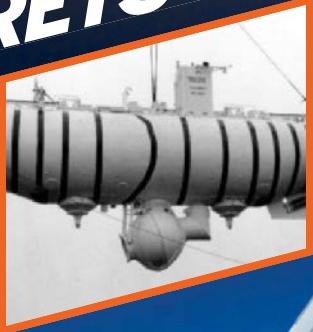
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# JOURNEY TO THE MOON

INCREDIBLE VOYAGES AND  
THE SECRETS OF SURVIVAL



**A**s if sitting on top of an enormous rocket with the chemical energy of a small atomic bomb wasn't risky enough, Neil Armstrong, Buzz Aldrin and Michael Collins were about to become the first humans to visit another world. Previous missions had made the crew all too aware of the dangers of space travel, after three astronauts were killed in the Apollo 1 launch pad fire, but with years of training behind them, they bravely boarded the Columbia Command Module and waved goodbye to Earth.

The problems began when the Eagle Lunar Module started its descent to the Moon, as radio communication to Mission Control became patchy and the master alarm signalled a system overload. Even worse, Armstrong and Aldrin then realised that they were off course. Instead of heading for a smooth plain, they were approaching a crater field full of truck-sized boulders. After adjusting their trajectory, only five per cent of the descent fuel remained, giving Armstrong just 60 seconds to touch down.

After an incredibly tense minute, the Eagle had finally landed, and Armstrong and Aldrin set out into the Moon's thin atmosphere to take the most

famous steps in history. Getting to the Moon was only half the mission though, and as the astronauts hurtled back towards Earth, the Columbia's thin heat shield was all that protected them from temperatures of 2,760 degrees Celsius. Back on Earth, they were welcomed as heroes and provided invaluable knowledge to aid future Moon missions.

Now NASA has its sights set on another world, with plans to send humans to Mars by 2040. This deep-space mission presents a new set of risks, and requires sophisticated tech to ensure the crew can survive the 18-month round trip.

Sending humans to Mars is going to require the most powerful rocket in history, NASA's

Space Launch System (SLS). It is heavily inspired by the Saturn V, which propelled many of the Apollo missions into orbit, as both are made up of several stages. When each stage runs out of fuel, it is dropped to reduce weight, with the Saturn V having three stages and the SLS needing only two.

The two rockets are also a similar height and weight, but in order to ensure the SLS can get to Mars, NASA has made their new rocket more fuel-efficient and powerful. Its two rocket boosters can produce the same amount of thrust as all five of the Saturn V's first stage engines, helping it to take a crew further into space than ever before.



The Saturn V rocket launched Armstrong, Aldrin and Collins into lunar orbit

## Prepare for landing

**The Apollo Command Module brought the astronauts safely back to Earth**

### Antenna

A high-gain steerable antenna enabled telecommunications with Earth.



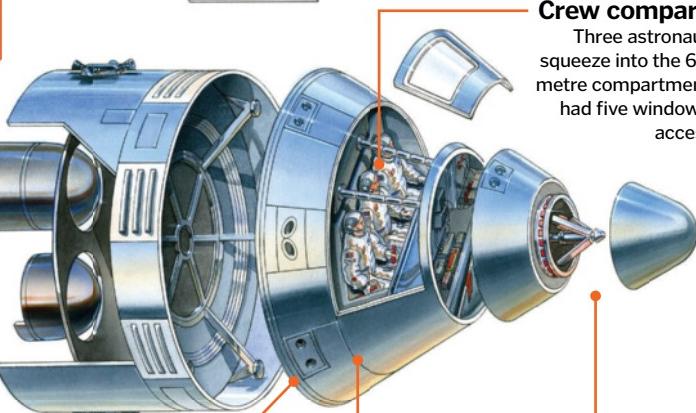
### Fuel cells

Hydrogen-oxygen fuel cells powered the crew's navigation, communication and life support systems.



### Reaction control system

12 reaction control thrusters on the Command Module helped to steer after separation from the Service Module.



### Crew compartment

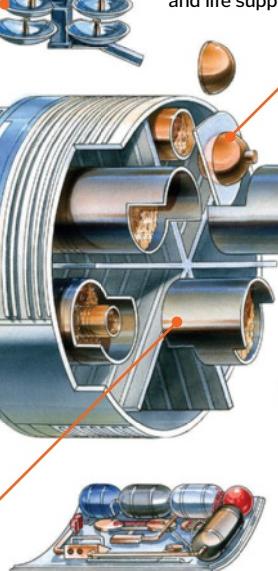
Three astronauts could squeeze into the 6.2-cubic-metre compartment, which had five windows and an access hatch.

### Main engine

The rocket engine helped propel the spacecraft into lunar orbit and then back towards Earth once the mission was over.

### Fuel tanks

Tanks of fuel and oxidiser powered the engine, and tanks of helium pressurised the fuel system.



### Heat shield

Brazed stainless steel honeycomb filled with resin helped protect the crew on re-entry into Earth's atmosphere.

### Service Module

Detached just before re-entry, the Service Module provided most of the Apollo spacecraft's power, storage and propulsion.

### Parachutes

The nose cone contained parachutes designed to slow down the spacecraft as it fell to Earth.

## ESSENTIAL KIT: 1960s astronaut

**1 Spandex undergarment** Water was piped across the astronaut's body to keep them cool in temperatures up to 120 degrees Celsius.

**2 Teflon-coated suit** 25 layers of material helped protect the astronaut from extreme heat and impacts from micrometeoroids.

**3 Helmet** The high-strength plastic helmet screwed onto the suit and featured a gold-plated visor to protect the eyes from intense sunlight.



## The route to the Moon

How did the dangerous Apollo 11 mission unfold?

### 1 We have lift-off

The Saturn V rocket launched on 16 July 1969 and after 1.5 Earth orbits was on course for the Moon.

### 4 The Eagle has landed

On 20 July 1969, the Eagle landed on the Moon and Armstrong and Aldrin stepped onto the surface.

### 7 Splash landing

On 24 July 1969, the Command Module re-entered Earth's atmosphere, landing in the Pacific Ocean.

### 2 Lunar orbit

The Command/Service Module (CSM) docked with the Lunar Module inside the rocket before entering lunar orbit.

### 5 Farewell to the Moon

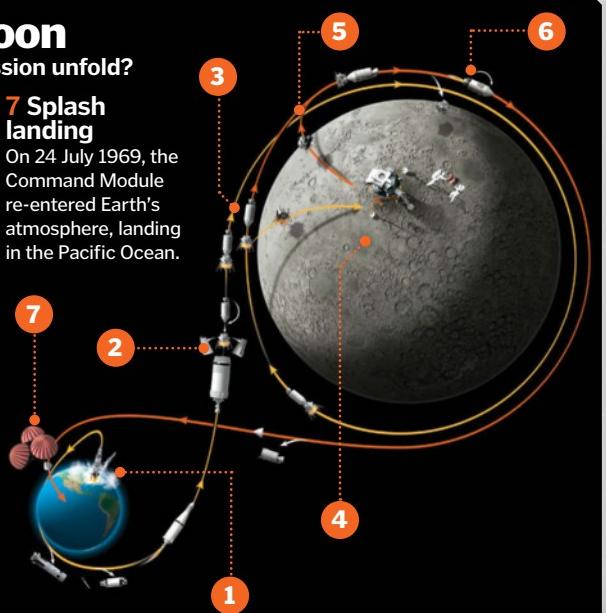
After 21 hours and 36 minutes on the Moon, the astronauts piloted the Eagle back to the CSM.

### 3 Setting the Eagle free

Armstrong and Aldrin entered the Lunar Module and separated from the CSM, then began their descent.

### 6 Reunited

Once Aldrin and Armstrong were back on the CSM with Collins, the Eagle was detached and stayed in lunar orbit.



# RACE TO THE SOUTH POLE

## How one team survived the perilous journey to the bottom of the world

In 1911, with the North Pole already conquered, many explorers set their sights on the South. Two rival teams embarked on the dangerous trek across Antarctica, but sadly only one would return. With several depots already set up along their route, Norwegian explorer Roald Amundsen and his team of five used only four sledges and a pack of 52 dogs to carry supplies.

Battling fierce winds and temperatures of -60 degrees Celsius, they finally reached the Pole on 14 December, beating Robert Scott and his British team by nearly five weeks. Scott had set off 13 days after Amundsen along with 15 men, 13 sledges, two motorised sledges, ten ponies and 22 dogs. Unable to cope with the extreme conditions, the motorised sledges and ponies were abandoned, and eventually 11 of the men turned back with the dogs. Scott and four others carried on, only discovering they had been beaten when they saw the Norwegian flag at the Pole. Disheartened and weak, hypothermia and starvation set in, and the cruel continent claimed their lives before they made it back to base camp.

Thankfully, modern day polar explorers are much better equipped to deal with the freezing conditions of the Arctic and Antarctic, and have plenty of ingenious technology on hand to help them survive their arduous journeys.

### Antarctic explorers

How the Norwegian team became the first to reach the South Pole

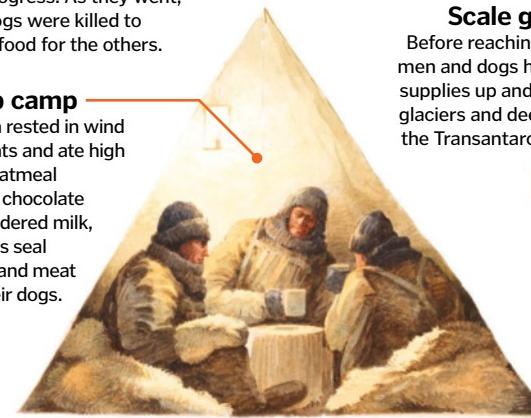


#### Full speed ahead

Four sledges were pulled by 52 dogs, helping the team make quick progress. As they went, some dogs were killed to provide food for the others.

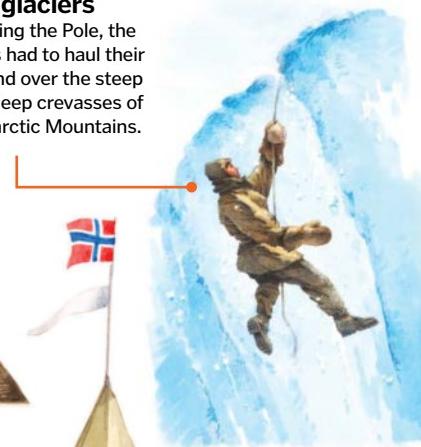
#### Set up camp

The men rested in wind cloth tents and ate high calorie oatmeal biscuits, chocolate and powdered milk, as well as seal blubber and meat from their dogs.



#### Scale glaciers

Before reaching the Pole, the men and dogs had to haul their supplies up and over the steep glaciers and deep crevasses of the Transantarctic Mountains.



#### Reach the Pole

With frostbitten hands and faces, they finally reached the South Pole. After erecting a tent, planting the Norwegian flag and taking photos, they began the 39-day journey back again.



## ESSENTIAL KIT:

### Polar explorer

#### Sledge

Equipment and supplies are pulled along in sledges attached to the explorers' harnesses.

#### Satellite beacon

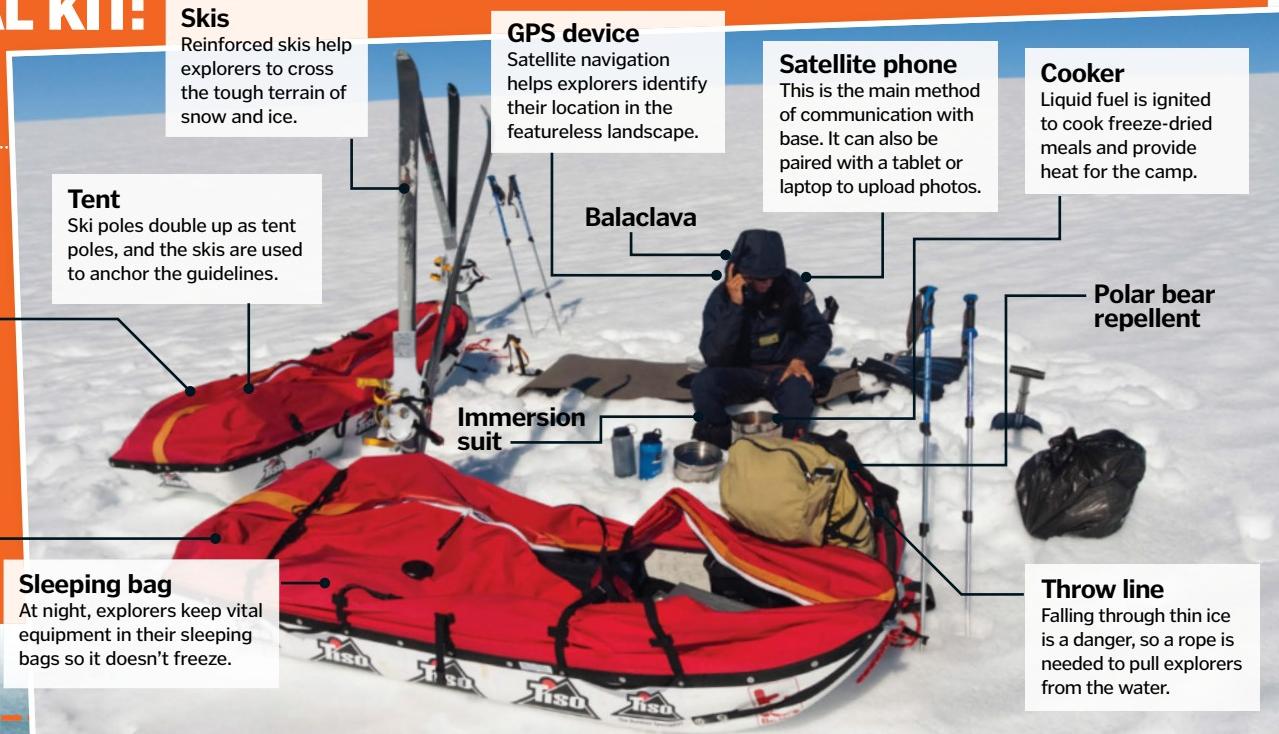
This back-up communication and tracking system can be used to send a signal back to base in case of an emergency.

#### Skis

Reinforced skis help explorers to cross the tough terrain of snow and ice.

#### Tent

Ski poles double up as tent poles, and the skis are used to anchor the guidelines.



#### GPS device

Satellite navigation helps explorers identify their location in the featureless landscape.

#### Immersion suit

At night, explorers keep vital equipment in their sleeping bags so it doesn't freeze.

#### Satellite phone

This is the main method of communication with base. It can also be paired with a tablet or laptop to upload photos.

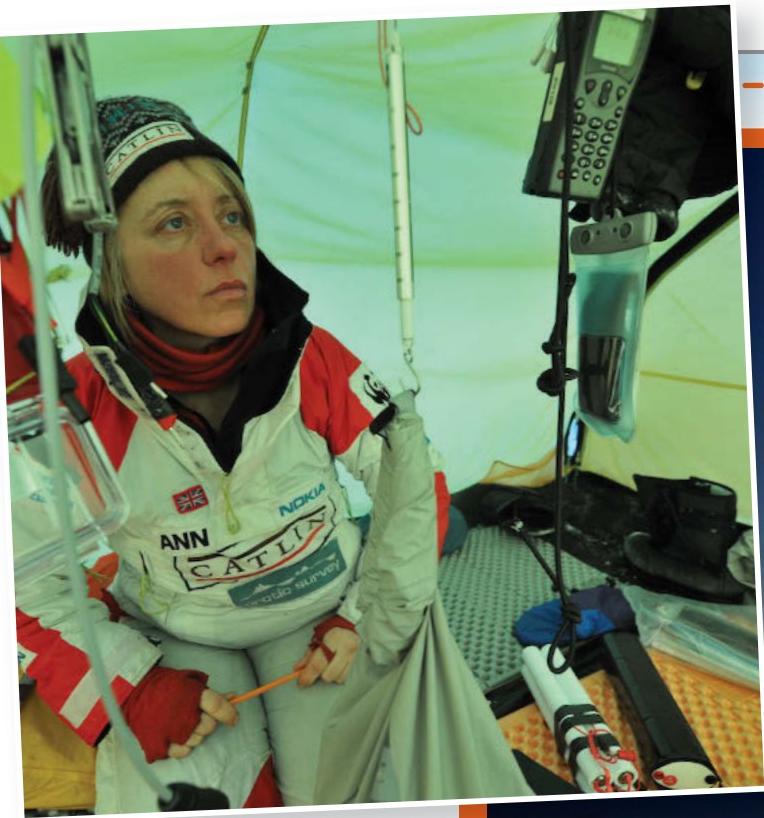
#### Cooker

Liquid fuel is ignited to cook freeze-dried meals and provide heat for the camp.

#### Polar bear repellent

#### Throw line

Falling through thin ice is a danger, so a rope is needed to pull explorers from the water.



Daniels has led three Catlin Arctic survey expeditions, helping scientists to study the ice

In total, Daniels has hauled a sledge for over 400 days and 4,800 kilometres on the ice

## The effects of hypothermia

What happens when your core body temperature drops below 37 degrees Celsius?

**32-35°C**  
Mild hypothermia

Shivering, fast breathing, tiredness, pale skin.

**28-32°C**  
Moderate hypothermia

Confusion, loss of judgement, difficulty moving, slow breathing.

**25-28°C**  
Severe hypothermia

Unconsciousness, shallow breathing, weak pulse, dilated pupils.

**Below 25°C**  
Death

Cardiac arrest, no detectable vital signs.

## Q&A

Polar explorer Ann Daniels discusses the perils and triumphs of a journey to the poles



Having never even worn a pair of walking boots before, Ann Daniels' introduction to explorer life came when she answered an advert for 'ordinary' people to travel to the North Pole. She has since become

one of the first women in history to reach the North and South Poles as part of all female teams, and has led numerous scientific polar expeditions.

### What is it like to journey to the Poles?

The South Pole is on land and the terrain is very similar day to day, so it's a battle of endurance to keep your mind occupied. But the North Pole is on a crust of ice floating on the ocean. The ice moves under you and ice floes crash against each other to form huge ridges. The panel of ice you're walking on can break at any time. You have to develop a knowledge of the different types of ice and every step is about decisions.

### What is the scariest moment you've ever faced?

I've been stalked by a polar bear for three days while I was on a solo expedition and a large male came to my tent. It was really difficult to frighten him away.

On another North Pole expedition we were storm bound and we couldn't get the tent up for three days. We couldn't eat, drink, cook, contact the outside world or even speak to each other because the wind was so bad. I had to come out from the covering to get our satellite beacon so I could send a signal to base to

say we were alive. When I got out, my body went so cold and I knew I was facing death. I couldn't warm up because I couldn't light the cooker, so it was all about the power of the mind – imagining a fire inside me and willing my body to come back to life.

### Have you suffered any serious injuries?

I've had frostbite and wet gangrene of my two middle toes and my little toe. As it hits the end of your frozen boot, the pain shoots through your whole body and it's excruciating. I also ate contaminated food once, which gave me horrendous diarrhoea. I can deal with most things, but when I fell into it and I had it in my hair and on my gloves – that was a real low point. You can't wash so you're just stuck with it.

### How does it feel to reach the end of a journey?

When you start, you think it's never going to end. 80 days is such an unimaginable amount of time to be exposed to those conditions. But about three days before you reach the pole, you realise that this big adventure you've been working towards for years is about to end, and you don't want it to. Then when you finally get there, you feel an enormous sense of achievement. You know what you had to go through to get to that point; nobody else will ever know that. It's complete euphoria.

#### Learn more

Find out more about Ann's polar expeditions and the conditions she faced at [www.anndaniels.com](http://www.anndaniels.com).

# THE FIRST DEEP-SEA VOYAGE

The Mariana Trench in the Pacific Ocean, around 2,000 kilometres east of the Philippines, is home to the deepest place on Earth. Known as Challenger Deep, it's just shy of 11,000 metres below sea level – if you could drop Mount Everest there, its peak would still be over two kilometres underwater. Until 1960 it had never been seen by human eyes, but that all changed when two brave hydronauts boarded the Trieste submersible.

Jacques Piccard and Don Walsh could barely sit down in the cramped observation sphere, with only 13 centimetres of steel to protect them from the cold temperatures and crushing pressure. When they reached the bottom, the window of the vessel began to crack, and they quickly began their ascent after spending just 20 minutes on the ocean floor. Nevertheless, they had entered the record books, and their observations of shrimp-like creatures had proved for the first time that marine life could survive at such depths.

It would be another 52 years before anyone dared to go back. In March 2012, movie director James Cameron piloted the DeepSea Challenger sub to the ocean floor, becoming the first person to make the trip alone. The custom vessel, which he helped to design, allowed him to spend several hours at the bottom, and record the entire journey in 3D using eight high definition (HD) cameras.

**"Only 13cm of steel protected them from crushing pressure"**

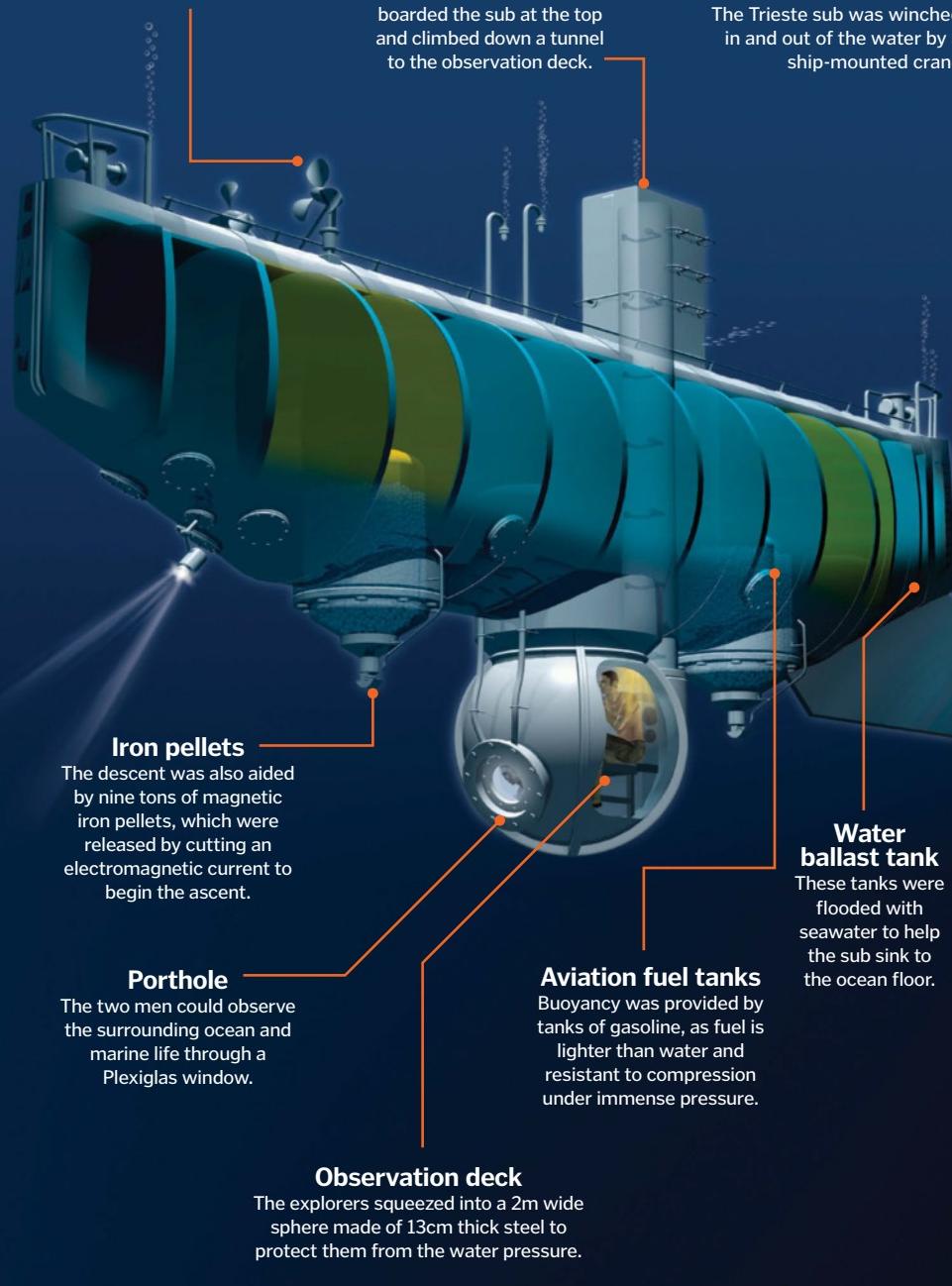


## The Trieste sub

The deep-sea craft that first reached Challenger Deep

### Propellers

The sub could be manoeuvred horizontally by controlling the speed of the propellers.



### Hostile natives

Local people may be unwelcoming to visitors, as Captain James Cook discovered when he was murdered by islanders in Hawaii in 1779.

### Hypothermia/ frostbite

Robert Scott and some of his team succumbed to hypothermia and frostbite on their return journey from the South Pole in 1912.

### Starvation/ dehydration

If supplies run out, explorers must hunt for food and water to survive. Without the right nutrition, conditions such as scurvy can leave them ill and weak.

### Exhaustion

Pushing the body to its limits can prove fatal. In early 2016, polar explorer Henry Worsley died after suffering from exhaustion while attempting to cross Antarctica unaided.

### Ferocious animals

Out in the wilderness, all sorts of creatures can pose a threat. In 2006, it was a stingray that took the life of crocodile hunter Steve Irwin.

### Deadly diseases

Unknown diseases are a major threat in new places. While travelling across Africa, explorer David Livingstone contracted malaria and died in 1873.

# REVISITING THE MARIANA TRENCH

## DeepSea Challenger

James Cameron's high-tech sub that sent him solo to the ocean floor

### Hull

70 per cent of the sub's volume is made up of foam, providing both buoyancy and structural support.

### Vertical design

The unique vertical design enables the sub to descend and ascend quickly, maximising time on the bottom.

### Lighting array

A two-metre panel of LED lights can illuminate 30 metres through clear water.

### Pilot sphere

6.4 centimetres of steel protect the pilot from the crushing pressure of the deep.



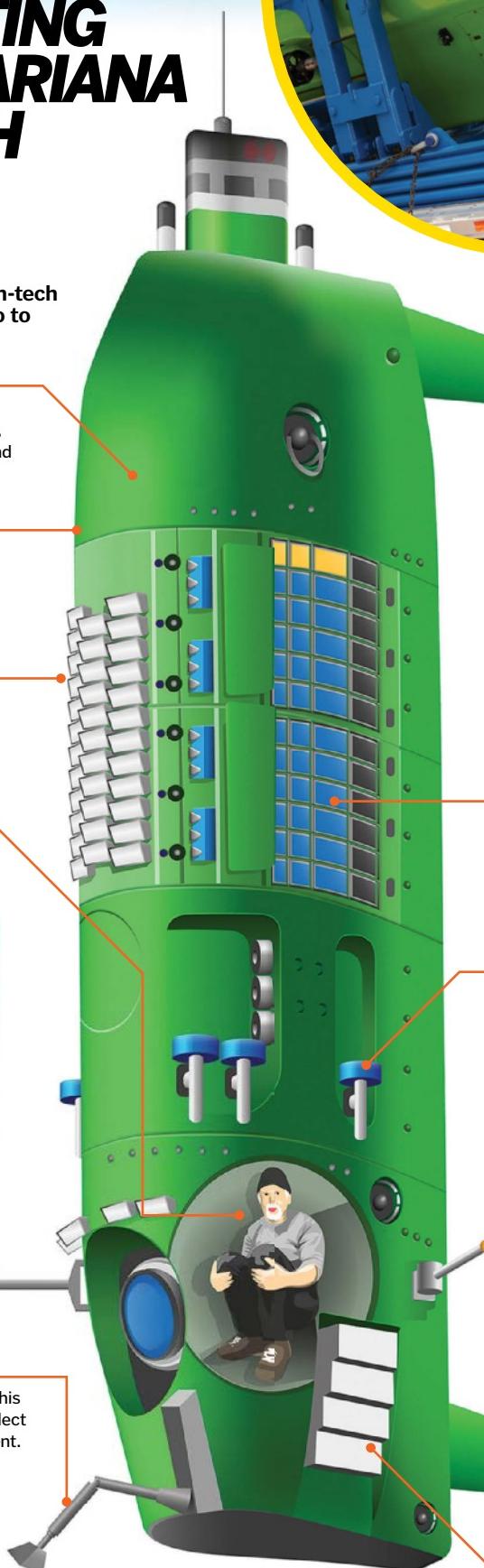
### Booms

Two hydraulic poles on the side of the vehicle hold a powerful spotlight and a pair of HD cameras.



### Manipulator arm

Controlled with a joystick, this arm enables the pilot to collect samples of seafloor sediment.



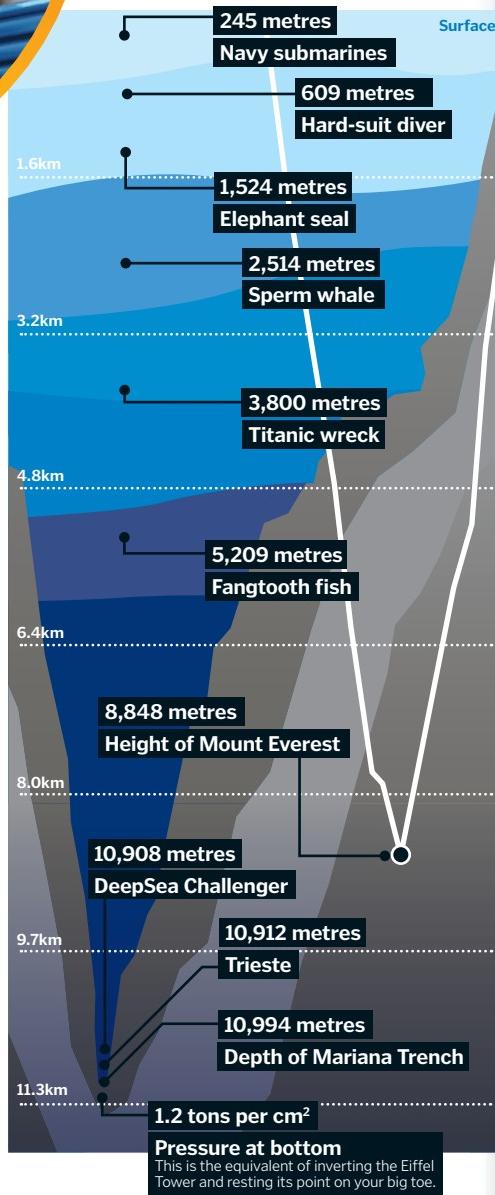
**"The custom vessel allowed him to spend several hours at the bottom and record it in 3D"**



Titanic and Avatar director James Cameron with the DeepSea Challenger

## How deep?

The Mariana Trench lies deeper than Everest is tall



## ESSENTIAL KIT: Deep-sea explorer

**1 Pressure-resistant capsule** To survive the huge pressures at the bottom of deep seas, explorers must be in a strong, pressure-resistant capsule.

**2 Oxygen** The air-tight capsule must have a supply of oxygen and a method of removing carbon dioxide to enable the pilot to breathe.

**3 Warm clothing** Temperatures can fall below freezing at the bottom of Challenger Deep, so the explorers must wear several layers to keep warm.



# JOURNEYING ACROSS THE PACIFIC OCEAN

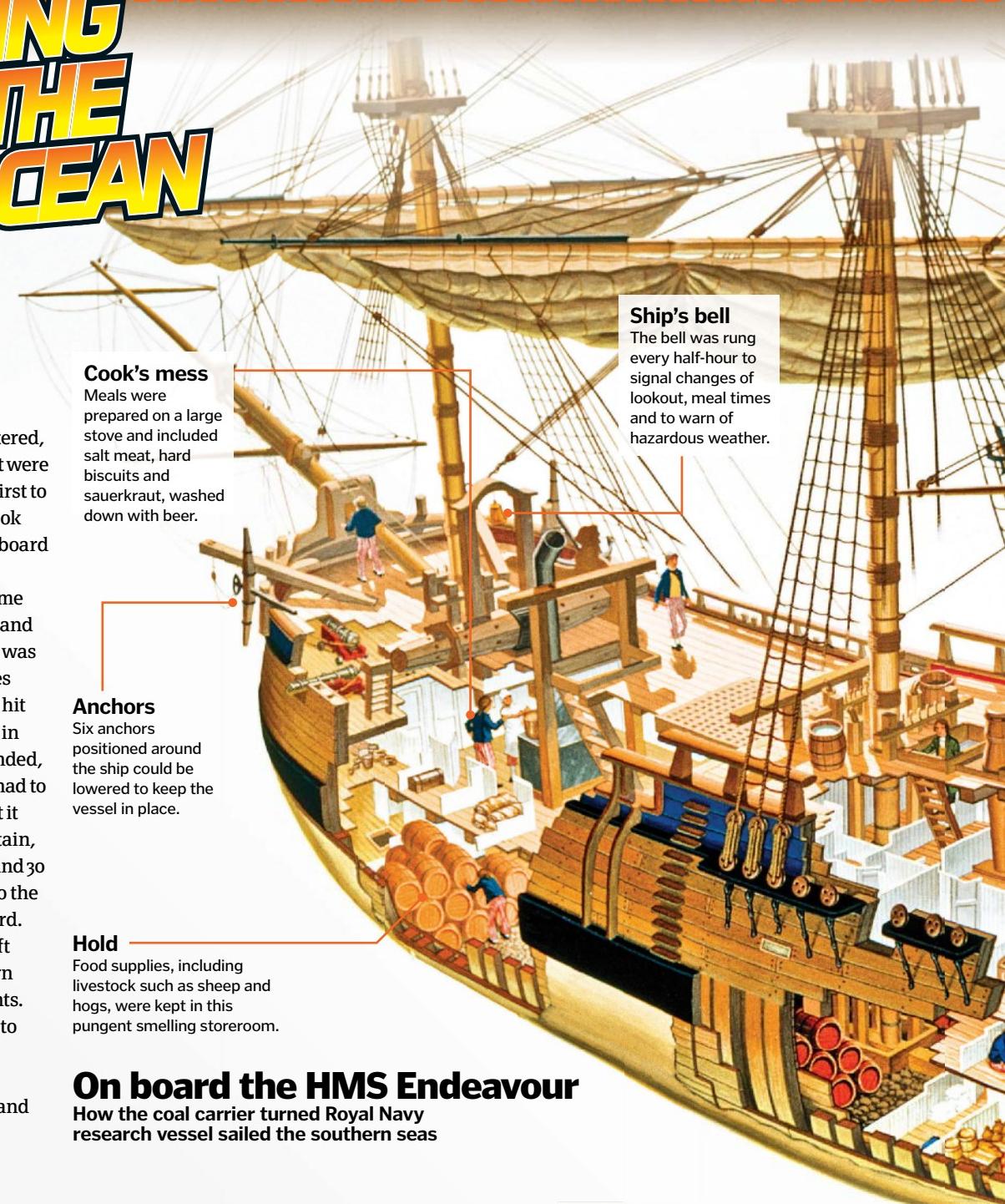
## CAPTAIN COOK'S TROUBLED FIRST VOYAGE ACROSS THE SOUTH SEAS

With much of the Pacific Ocean still uncharted, rumours of a mysterious southern continent were rife in 18th century Europe. Eager to be the first to lay claim to it, Britain sent Captain James Cook and a crew of 93 men on a secret mission on board the HMS Endeavour.

During their three-year voyage they became the first Europeans to land on New Zealand and the east coast of Australia, but their journey was plagued with problems. About 130 kilometres north of modern-day Cairns, the Endeavour hit part of the Great Barrier Reef, ripping a hole in the hull. Facing the possibility of being stranded, the crew set about repairing their ship and had to throw 50 tons of equipment overboard to get it moving. They eventually set sail back to Britain, but not everyone survived the journey. Around 30 men died from malaria and dysentery due to the cramped and unsanitary conditions on board.

Nowadays, with very little of the planet left uncharted, research vessels are used to learn more about the world's oceans and continents. The Tara Expeditions schooner boat is built to sail in extreme conditions and has been travelling around the world since 2003, conducting science experiments to understand the impacts of climate change.

The Tara Expeditions boat has travelled over 300,000 kilometres around the world so far



## On board the HMS Endeavour

How the coal carrier turned Royal Navy research vessel sailed the southern seas

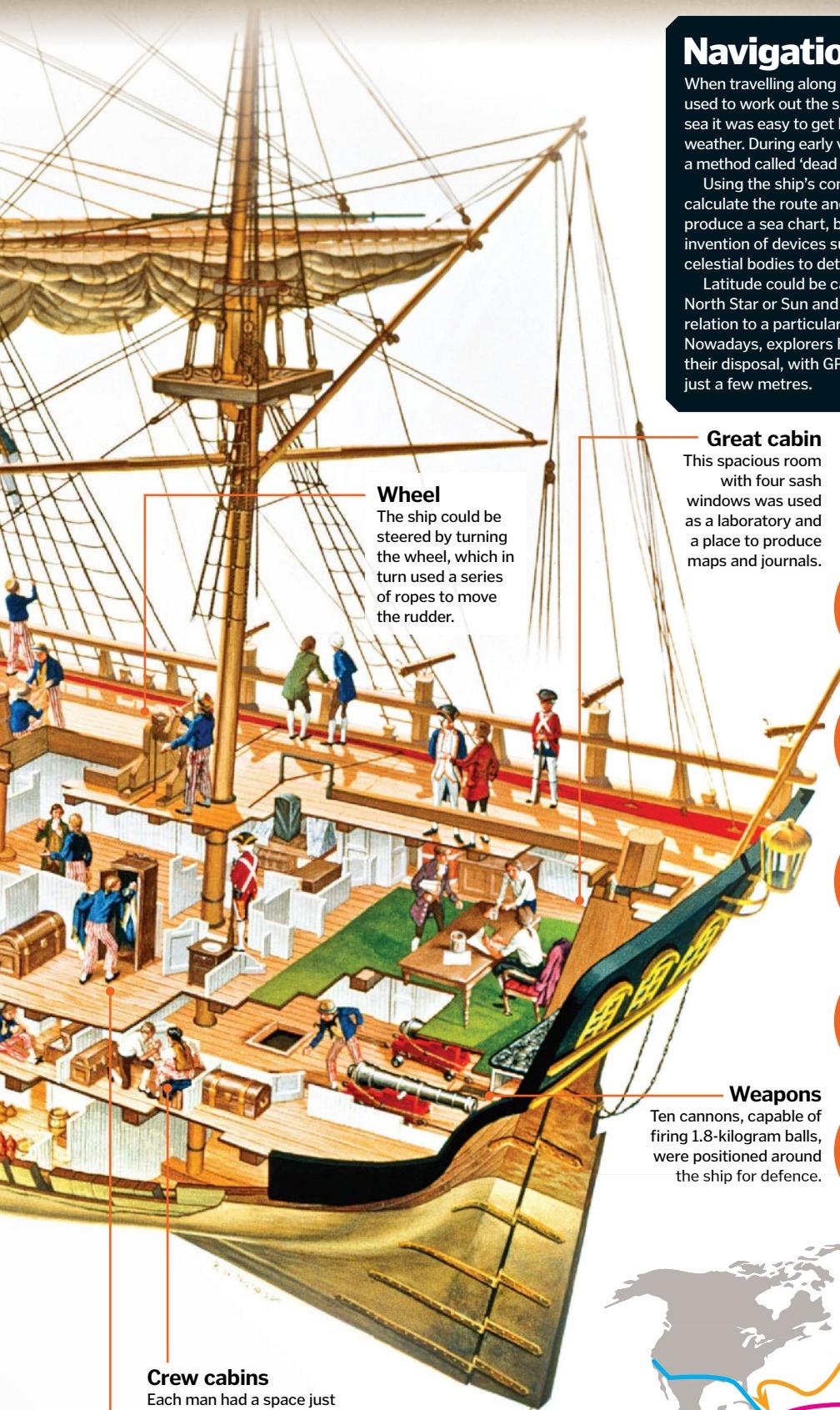
### ESSENTIAL KIT: Marine explorer

**1 Map** Using a compass and map, a marine explorer can take a bearing to work out which direction they need to travel in.

**2 Binoculars** When land appears on the horizon, a pair of binoculars will help them get a better look of what lies ahead.

**3 Compass** The magnetic needle within a compass will align with Earth's magnetic field to tell the explorer which way is north.





### Crew cabins

Each man had a space just 35cm wide and under 1m tall in which to sleep, so there wasn't much room to stretch out.

### Civilian cabins

This first-class accommodation was reserved for civilian guests, such as astronomer Charles Green, and also for Captain Cook himself.

## Navigation at sea

When travelling along a coast, landmarks could be used to work out the ship's position, but on the open sea it was easy to get lost, particularly in turbulent weather. During early voyages, European mariners used a method called 'dead reckoning' to navigate.

Using the ship's compass heading and speed, they could calculate the route and distance the ship had covered to produce a sea chart, but this was often inaccurate. With the invention of devices such as the sextant, explorers could begin using celestial bodies to determine their location.

Latitude could be calculated by measuring the angle between the North Star or Sun and the horizon, and the movement of the Moon in relation to a particular star could be used to work out the longitude. Nowadays, explorers have much more accurate navigation methods at their disposal, with GPS capable of determining their position to within just a few metres.

A sextant was used to work out a ship's position based on the Sun, Moon and stars



## Ground-breaking journeys from history

### 1 Christopher Columbus

**Date of voyage:** 1492-1493  
**Mode of transport:** Santa María, Niña and Pinta ships  
Although Vikings had first visited North America five centuries earlier, Columbus is credited for opening up the Americas to European colonisation.



### 2 Ferdinand Magellan

**Date of voyage:** 1519-1521  
**Mode of transport:** Fleet of five ships  
Magellan led the first circumnavigation of the globe but was killed in battle on the voyage. Only one of his ships completed the journey, returning to Spain in 1522.



### 3 Ibn Battuta

**Date of voyage:** 1325-1354  
**Mode of transport:** Camel, donkey, sailing boat  
Muslim explorer Battuta covered over 120,000 kilometres in 30 years. He visited much of the known Islamic world, from southern Europe to Southeast Asia.



### 4 Amelia Earhart

**Date of voyage:** 1937  
**Mode of transport:** Lockheed Electra aircraft  
After becoming the first woman to fly solo across the Atlantic, Earhart set off to fly around the world, but disappeared before she could complete the journey.



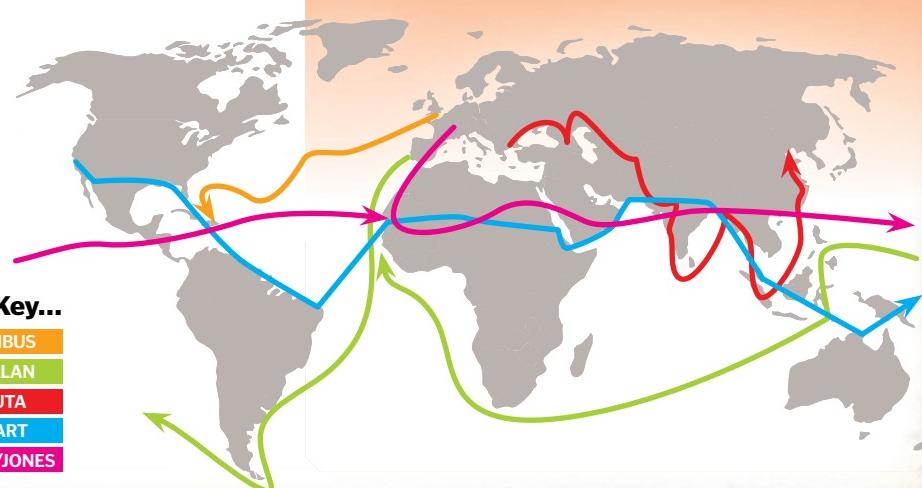
### 5 Bertrand Piccard and Brian Jones

**Date of voyage:** 1999  
**Mode of transport:** Breitling Orbiter 3 balloon  
Piccard and Jones completed the first circumnavigation of the globe in a hot air balloon.



### Route Key...

COLUMBUS
MAGELLAN
BATTUTA
EARHART
PICCARD/JONES



# THE WORLD'S GREATEST LIVING EXPLORER

**Sir Ranulph Fiennes reveals his most difficult journeys and what happens when things go perilously wrong on the ice**

During his 50-year career as an explorer, Sir Ranulph Fiennes has become the first person to reach both poles, completed the first circumnavigation of the globe along its polar axis, and bagged the title of the oldest Briton to reach Mount Everest's summit. His incredible list of achievements led the Guinness Book of World Records to declare him the World's Greatest Living Explorer in 1984, and he has shown no signs of slowing down since.

Only last year, despite having lost several fingers to frostbite and undergone double heart bypass surgery, a 71-year-old Sir Ranulph completed one of the toughest footraces on Earth. After running 251 kilometres across the Sahara Desert in temperatures over 50 degrees Celsius, he became the oldest Briton to complete the Marathon des Sables, and brought his fundraising total up to £18.2 million.

Now he is already planning his next challenge, but took some time out to speak to **How It Works** about his incredible career so far.

## Which explorers, from history or the present day, most inspire you?

Captain Cook in the 1770s. Life on a ship was very difficult in those days, even in known waters, and he led the way to Australia and Canada. In my lifetime, there's Wilfred Thesiger who explored hot deserts, and the greatest polar explorer of all time, Captain Scott. His expeditions produced more scientific results than all the other international polar expeditions of the first half of the 20th century.



Sir Ranulph Fiennes has completed over 17 expeditions and broken numerous world records

## What are the most important qualities you think an explorer should have?

It would take quite a few pages to list all of the qualities I look for in people that we take on expeditions. I think they need to be equable people that don't, when they're suffering, become unpleasant towards others. There's lots of suffering, hunger, crotch-rot, gangrene and so on, which can make people testy. They also need to be very calm and capable of balanced thought. Not too much optimism and not too much pessimism, but as near to realistic thinking about the situation as is possible. Plus they need to be pretty determined.

## How has technology changed the way you complete your expeditions?

The clothing has come on in leaps and bounds. We started with wolf skins and I have fallen into the polar sea, broken through ice and swam around for a bit, and didn't die because of

wearing that stuff. Then we switched to

Gore-Tex in the late 70s or early 80s.

The communications set-up has got incredibly light. You now have a satellite telephone in your pocket, instead of carrying 30 pounds [13.6 kilograms] of high-frequency radio and antenna, and you can use it in your tent while having a cup of coffee instead of going outside, putting up the antenna and going out every five minutes to change the frequency by winding in a wire.

For navigation, as of the late 80s or early 90s, we started using GPS, which was a huge improvement. I used to navigate using a sextant or a theodolite. The theodolite had a tripod, which was heavy. A sextant was a lot lighter but not so easy to use accurately. Also it took a long time to operate outside in the cold when you wanted to be inside the tent. Now you just press a button on your GPS to get your position.

## Have there been any occasions when your equipment has failed you on an expedition?

I'm sure there must have been many but I can't remember a lot of them so they can't have been too bad. We designed stainless steel sledges for

the Arctic and the Antarctic, and in Antarctica we stupidly unloaded the ship using them. When loading them with 45-gallon drums to take inland, they buckled. We didn't realise until the ship had left us, so had a very difficult repair job to do out there without much equipment.

## What do you think is the most important piece of kit for any explorer to have?

I would say a rescue beacon is a vital bit of kit if you want to stay alive in bad circumstances. You must have some form of communication so that if things go badly wrong you can be rescued.

## What is the most difficult challenge you have ever faced?

I think finding the lost city of Ubar in the Arabian desert. It took us 26 years and eight separate expeditions to find this city, which had disappeared a couple of thousand years ago. We used photos taken from space by NASA but they only helped us know where the city was not [located]. We found it thanks to the most incredible luck, and we think we deserved it after 26 years of looking.

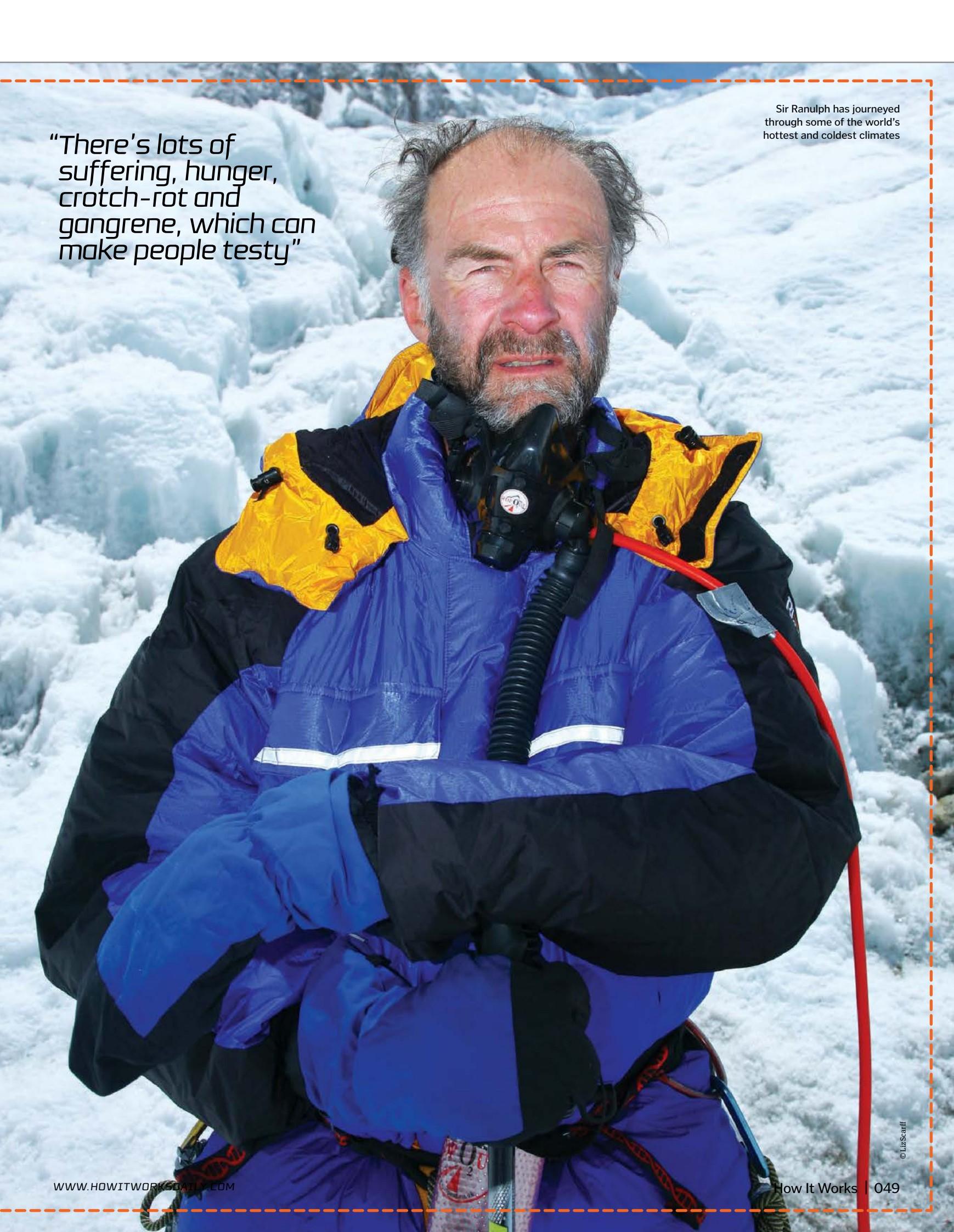
## Are there any expeditions you regret doing?

I regret the expedition in 2013 called The Coldest Journey. It didn't succeed because it turned out there was a crevasse belt there, and we had two 25-ton snowcats falling into them. If they had both fallen in at the same time, they would still be there. There is no way of getting a 25-ton vehicle out in a place like that, so we were very lucky that they both didn't.

But the six-man team had stayed in them for seven months, when average temperatures were well down below -50 degrees Celsius. It was very unfortunate because we thought we were successful climbing up to 11,000 feet [3,353 metres] in blue ice and crevasse zones, only to get stuck by a nasty little belt.

## Can you describe the scariest moment you have faced in your career?

Moving through very weak sea ice in fog with Charlie Burton in 1982 when we did the first complete crossing of the Arctic Ocean in a single season. We went over very lethal ice conditions. We had sledges and skidoos, and each skidoo weighed about 600 pounds [272 kilograms]. We were going over half-inch [1.3-centimetre] thick sea ice, and on one occasion I did actually fall through, and the skidoo and the sledge went down 17,000 feet [5,182 metres] to the seabed.



**"There's lots of suffering, hunger, crotch-rot and gangrene, which can make people testy"**

Sir Ranulph has journeyed through some of the world's hottest and coldest climates



# How to build an island

## Discover the incredible megastructures that extend a country's land mass thanks to some ingenious engineering

**C**onstructing islands is no longer solely the job of nature, as advances in engineering have resulted in several man-made structures popping up around the world. From floating islands that are home to single dwellings, to reclaimed land that can

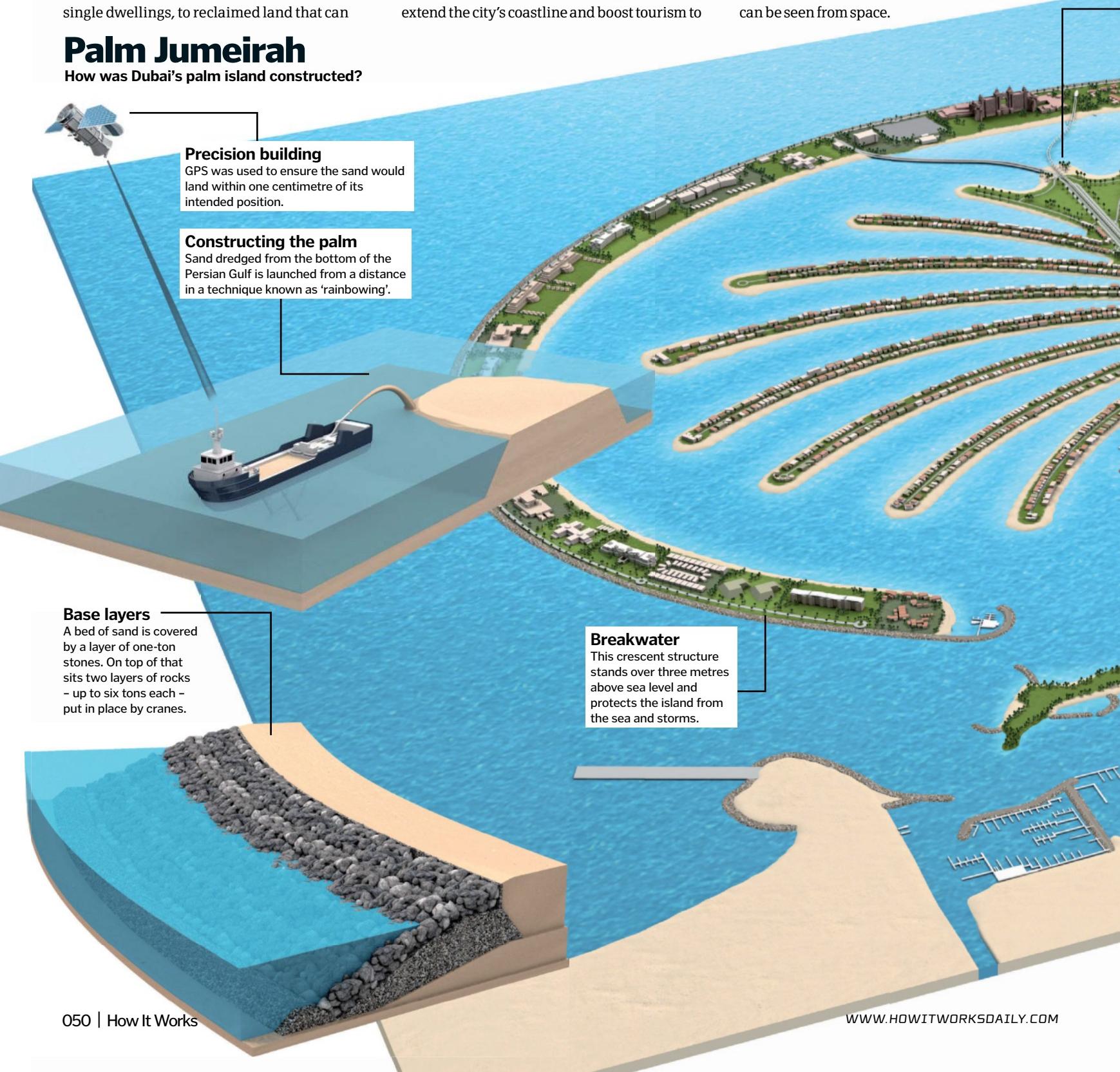
support entire communities, creating new terrain is now easier than ever.

The world's largest example is Palm Jumeirah, the palm tree-shaped island off the coast of Dubai in the United Arab Emirates. Designed as a way to extend the city's coastline and boost tourism to

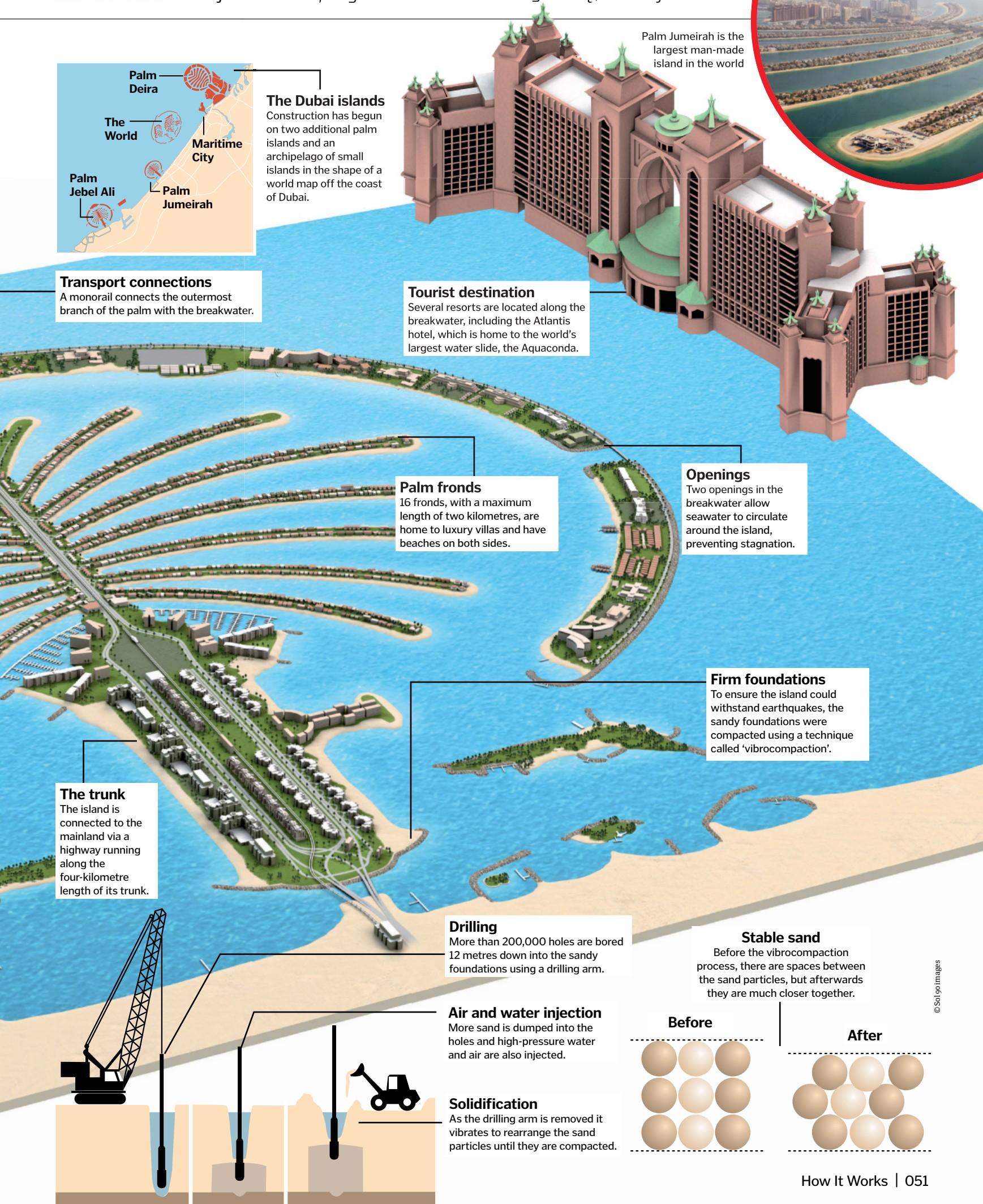
the area, the structure is made from all-natural materials and juts five kilometres out to sea. It was built by some of the world's best engineers using 94 million cubic metres of sand and 5.5 million cubic metres of rock, and is so big that it can be seen from space.

### Palm Jumeirah

How was Dubai's palm island constructed?



**DID YOU KNOW?** Palm Jumeirah took five years to build and cost £8.5 billion (\$12 billion) in total





# Reclaiming land

The methods used to create new land from oceans, rivers and lakes

Not to be confused with landfill – the mounds of rubbish left to decompose – land fill is reclaimed ground created from bodies of water. The simplest method of this land reclamation, and the one used to build Dubai's Palm Jumeirah, is called hydraulic fill, which involves dredging sediment from the seabed and using hydraulic pumps to fill in new land. This is the process currently being carried out in the South China

Sea, where large dredger barges are controversially piling sand onto coral reefs to create new islets.

However, if the sediment on the surrounding seabed is contaminated, or if the reclamation area is too soft to build on, then another method called deep cement mixing can be used. This involves injecting cement into the seabed and mixing it with soil. It then hardens into cement

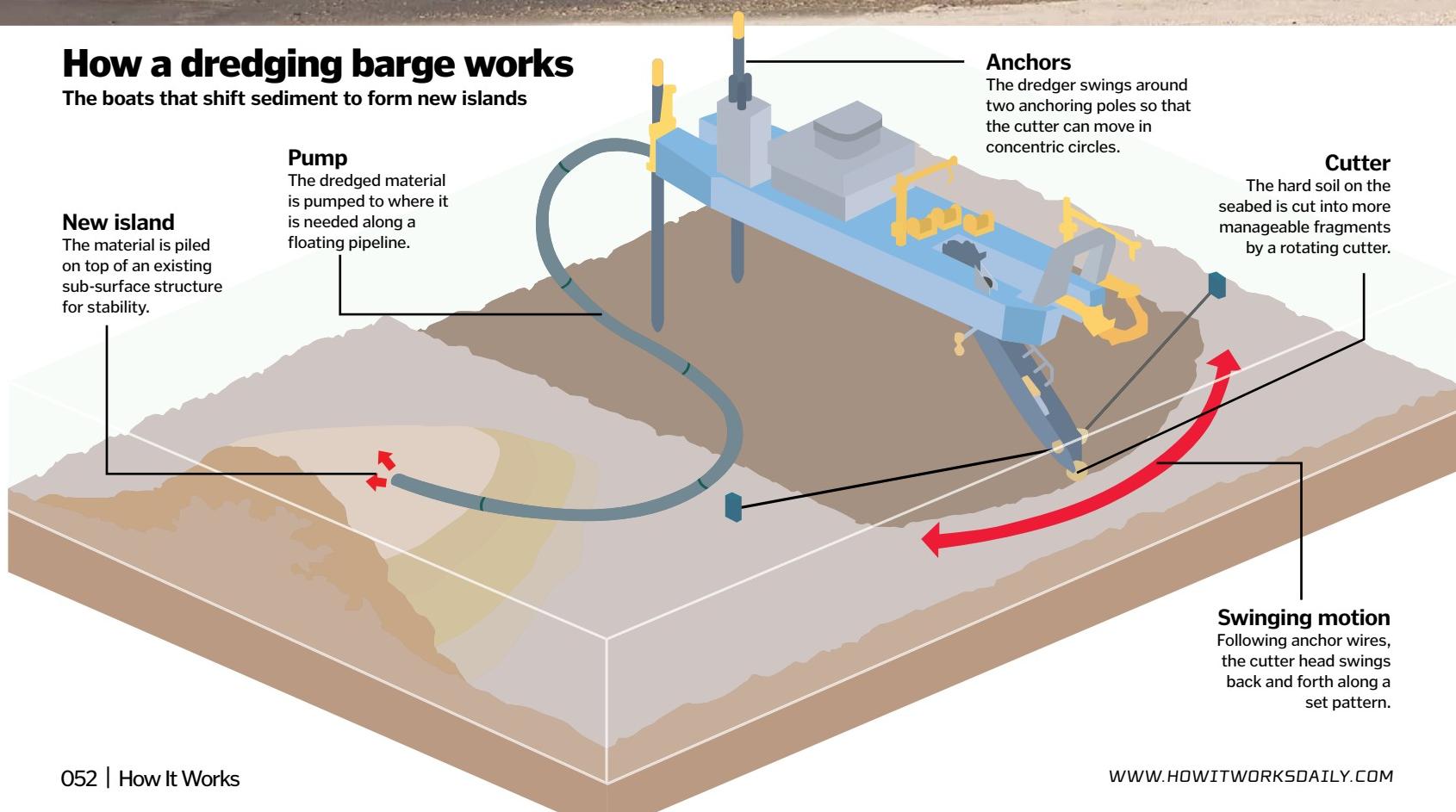
columns, which provide strong support for the new land. This method has been used to expand Hong Kong International Airport, which is already built on an artificial island, by 650 hectares, making space for a new runway. If more land is needed for agricultural purposes, then existing flooded wetlands can be drained by means of ditches or pipes that run into streams or other bodies of water.



Dredging boats sometimes use a technique called 'rainbowing', where they spray layers of sand to build up new land

## How a dredging barge works

The boats that shift sediment to form new islands



# Rubbish islands

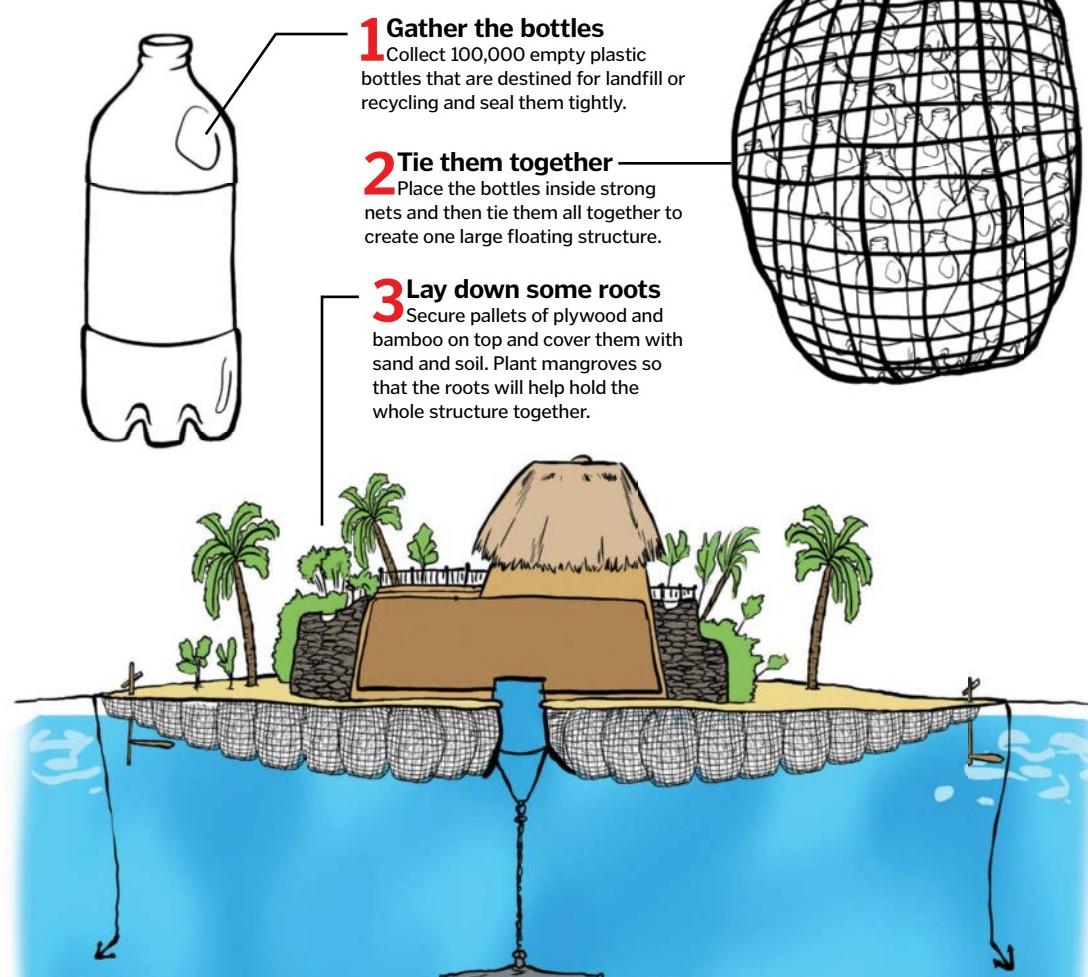
Building houses on floating plastic bottles is the ultimate in eco-living

British artist Richard Sowa has his own private island, but instead of buying it with a small fortune, he made it himself. Joyxee Island floats just off the coast of Mexico on top of approximately 100,000 plastic bottles. As the bottles are sealed and kept in darkness beneath the island, they don't deteriorate in the Sun's ultraviolet rays, and the roots of mangroves planted above help to hold them all in place. This has created an island that is 25 metres in diameter and strong enough to support a two-storey home, complete with a

solar-powered waterfall and a wave-powered washing machine. The island is anchored in place by wooden posts driven into the seabed, and is also tethered to the coast by a long rope. Joyxee Island is Sowa's second floating creation, as its predecessor, Spiral Island, was beached by hurricane Emily in 2005. After launching a Kickstarter crowdfunding campaign, which raised over \$9,000, he was able to rebuild it in a safer location.

## How to make a floating island

A step-by-step to creating your very own eco-paradise



Sowa's first creation, Spiral Island, survived for seven years, and washed up on a beach after hurricane Emily

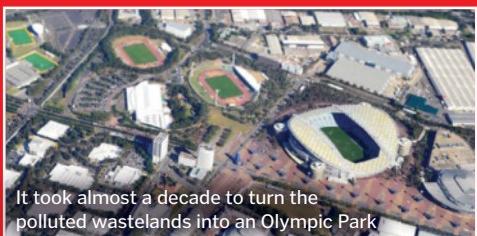
## Land reclamation success stories



The island of Manhattan has grown upwards and outwards over the last 400 years

### New York

Manhattan Island used to be a thin crop of marshland, but since 1609 it has expanded. The southwest tip was once part of the Hudson River but rock excavated during major construction projects and sand dredged from the harbour were used to create the Battery Park City area.



It took almost a decade to turn the polluted wastelands into an Olympic Park

### Sydney Olympic Park

The area on which the 2000 Summer Olympics were held was originally wetland, but in the 20th century it had been filled with industrial waste. In 1992, work began to transform the area. It cost over A\$100 million to decontaminate it for the construction of the Olympic Park.

2,000 hectares of land have been reclaimed to extend the port of Rotterdam



### Netherlands

Vast areas of the Netherlands have been reclaimed from lakes and the North Sea. Historically, windmills were used to pump water off the land, but now electric pumps and dykes are used to hold back the water. Today, about 27 per cent of the Netherlands is below sea level.



## Faking a click

The tiny screen of the Apple Watch includes its own 'taptic feedback' engine

# Haptic feedback

The touchscreens that can create virtual clicks

**T**he term 'haptic' comes from the Greek word for touch, and it refers to feedback from electronic devices that uses your sense of touch to alert or inform you. The rumble motors in a game console controller and the vibrate function in a phone are both simple examples of haptic feedback.

But haptic technology can be a lot more subtle too. Apple's newest touchscreens can simulate the physical sensation of clicking a button, even on a completely immobile sheet of glass. This works using a special kind of electric motor, called a linear actuator, that briefly

vibrates at exactly the moment your finger presses the screen. Although there's no physical button to click downward, the jolt to your fingertip registers the same touch sensation as a button.

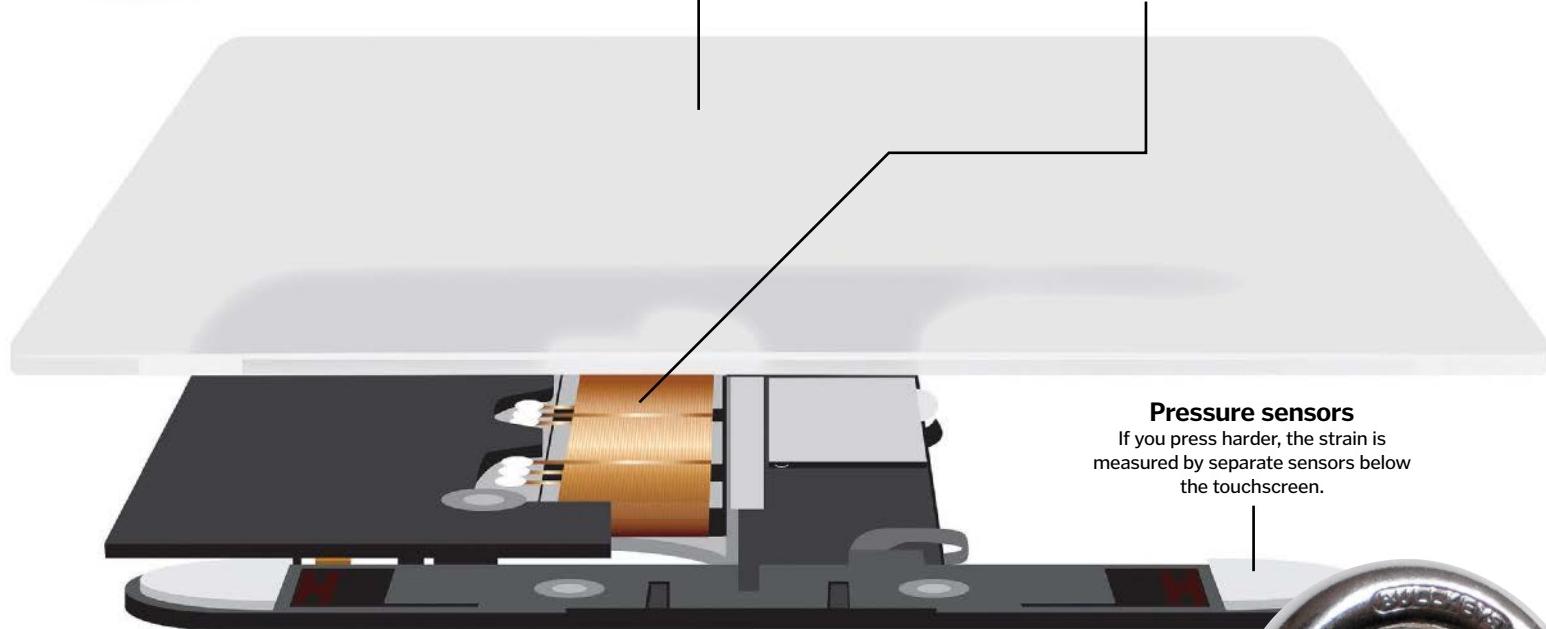
The trick relies on precise timing. Most phone vibration motors oscillate backwards and forwards at least ten times for a single activation, which feels more like a buzz than a click. Apple's 'Taptic Engine' can start and stop within a single cycle, and it tunes the length of the pulse to just ten milliseconds for a light touch, or 15 milliseconds for a full tap.

### Touchscreen

A glass screen covers the capacitive layer that detects finger contact and gestures.

### Taptic Engine

A permanent magnet surrounded by an electromagnet coil allows a precisely timed vibration that feels like a click.



# Padlocks

How does a lock know which is the right key?

**W**hen a padlock is shut, the U-shaped shackle is held in place by a spring-loaded bolt called a 'locking dog', which fits into a notch in the shackle arm. To unlock the padlock, you push the key into the rotating barrel in the centre. The ridges on the key push the tiny spring-loaded pins out of the way. Each pin is split into two halves, sitting one on top of the other in the same slot. The junction between the two halves is different for each pin

and it's arranged to correspond to the height of the ridges in that specific key.

When the key is pushed in, each of the pins slides just far enough in so that the gap between the two pin halves exactly reaches the edge of the barrel. When all the gaps line up, the barrel can rotate freely and push the locking dog out of the way. If you try the wrong key, some of the pins will always stick out past the edge of the barrel and stop it from turning.

Transparent padlocks let you practise your lock-picking skills!



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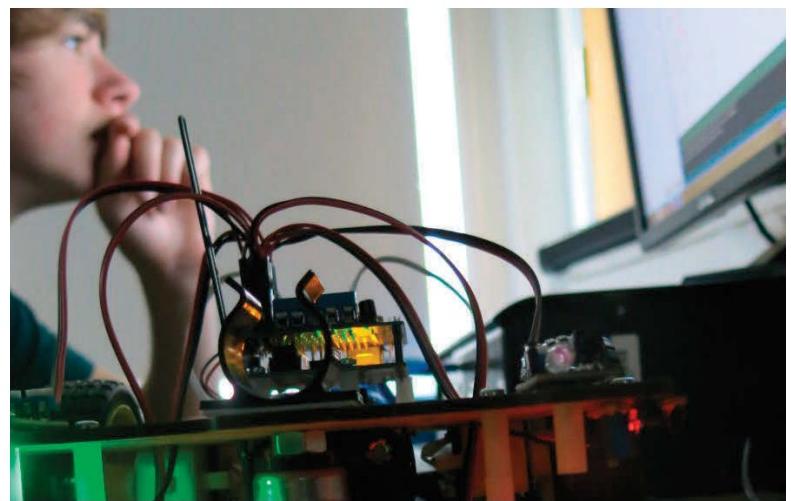
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# Firefighting tech

## The cutting-edge tools helping to battle blazes and save lives

Firefighters put their lives at risk every day to rescue people from burning buildings and stop the spread of raging fires, often with nothing more than a hose and a ladder. But the latest developments in firefighting technology are helping to make the job much easier and safer, speeding up rescue missions and keeping the firefighters out of harm's way.

Enormous, water-carrying aircraft can come to the rescue when widespread and unpredictable wildfires get out of control, and drones and robots can assist fire crews in city blazes, when visibility may be poor and structures are unsafe for humans to enter.

Even the method of dousing the flames is getting an upgrade, as water is being replaced

by chemical fire retardants that can help the re-growth of plants from the scorched terrain. In the future, there may be no need for human firefighters at all, as high-tech machines could tackle dangerous infernos unaided, using blasts of electric current to snuff out the flames in an instant.

*"The latest developments in firefighting technology are helping to make the job much easier and safer"*

### Drones

Korean researchers have developed a drone called the Fireproof Aerial Robot System that can fly and climb walls to search for fires in skyscrapers. It is able to withstand temperatures of over 1,000 degrees Celsius for more than one minute, and relays information to firefighters on the ground to aid rescue missions.

### Thermal imaging cameras

Thick smoke can sometimes obscure firefighters' view of the scene, so thermal imaging cameras can be used to locate hotspots and those in need of rescue. These cameras can be handheld by the firefighters themselves or mounted on drones or helicopters to relay aerial information to ground crews.

### Concrete pounder

The Controlled Impact Rescue Tool, developed by defence contractor Raytheon, fires blank ammunition cartridges to drive an impactor. This sends shockwaves through concrete structures and causes them to crumble. It can breach a concrete wall in less than half the time of traditional methods, helping firefighters reach those trapped inside.

### Hydraulic claws

The Heli-Claw drops vast amounts of shredded wood on scorched earth to rehabilitate the area.

### Fire prediction software

Prometheus is a computer program developed by the Canadian Interagency Forest Fire Centre, which uses climate and ecological data to predict wildfires and create simulations showing how they might spread. This information can then be used by firefighting crews to plan their approach.

### Robots

London's Fire Brigade trialled a team of firefighting robots that can climb stairs, shoot water and grab things with giant claws. They are designed to help extinguish fires involving acetylene gas cylinders, which can continue to heat up even after a fire has been extinguished.

### Air tankers

Global SuperTanker Services' converted Boeing 747-400 is the largest firefighting aircraft in the world. It can drop over 74,000 litres of retardant onto a fire and travel at 965 kilometres per hour to wherever it is needed in the world.

Firefighters wear heat-resistant suits made from Kevlar-based materials

### Fire retardants

As well as water, chemical-based fire retardants can also be used to both suppress an existing fire and prevent new fires from starting. One chemical often used is ammonium phosphate, and it is sometimes coloured red to show where it has already been dropped.

### Aircranes

Erickson's Aircrane helicopters can drop over 10,000 litres of water onto a fire, then refill from a nearby fresh or saltwater source in just 30 seconds. Once the fire has been extinguished, they can also drop seeds to encourage re-vegetation of the scorched land.

U.S. AIR FORCE  
71

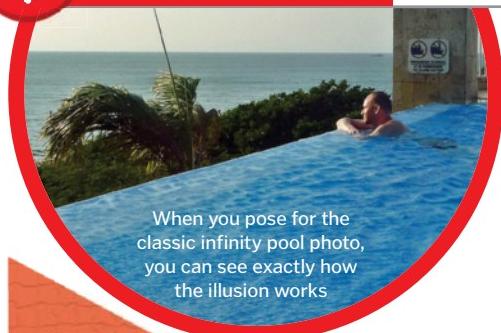
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### Fire shelters

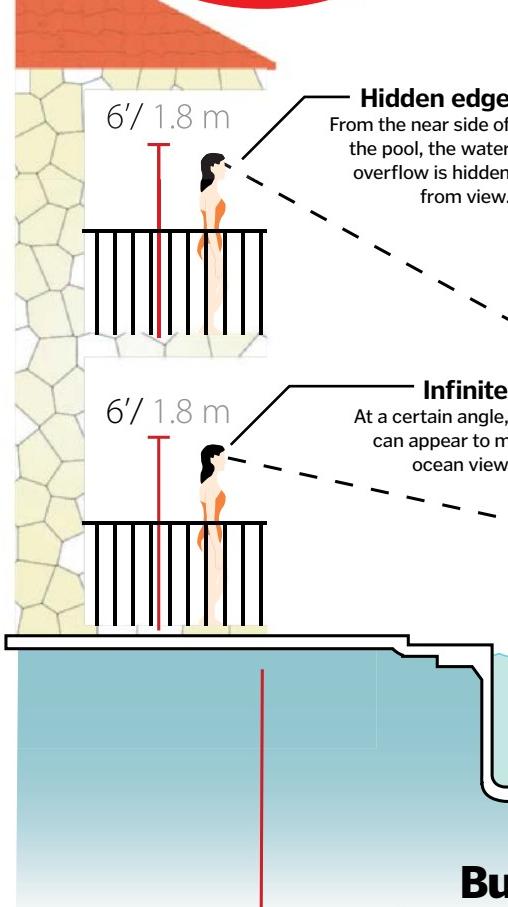
Designed as a last resort in emergency situations, these small foldable tents can protect firefighters from extreme heat and gas inhalation. NASA is currently working with the US Department of Agriculture's Forest Service to develop highly efficient and lightweight fire shelters made from spacecraft heat shield material.

### Electric wave blaster

Scientists at Harvard University have developed a device that can shoot beams of electricity at flames to snuff them out. When carbon particles in the flame become charged, the electric field essentially pushes the flame away from the unburnt fuel, extinguishing the fire without the need for lots of water.



When you pose for the classic infinity pool photo, you can see exactly how the illusion works



**Building the illusion**  
Infinity pools rely on carefully constructed sight lines

## Infinity pools

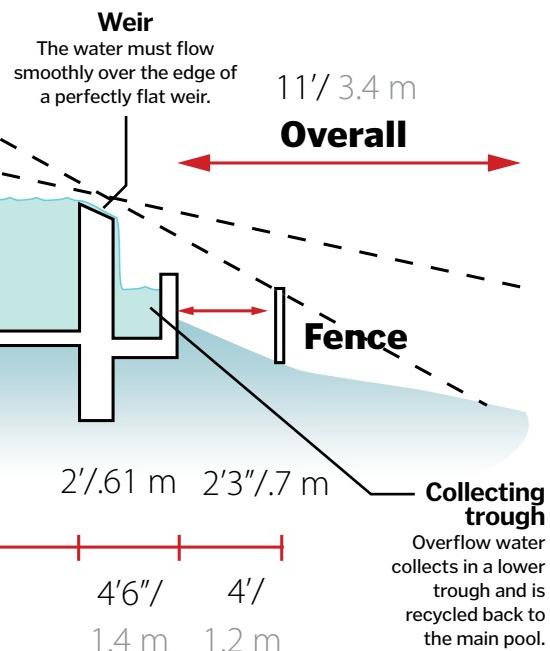
How hotels create these impossible floating pools

**T**ake a glass of water and fill it right to the brim. Now look at it sideways on, with your eye line only just above the water level. If you get it just right, you won't be able to see the far rim of the glass. Essentially, this is how infinity pools work.

Of course, if you were to climb into that glass of water, some of it would spill. When you got out again, the water level would drop and the rim

would be visible. Therefore, real infinity pools have to constantly pump water back into the pool. The far edge is actually a weir, with water flowing continuously over the edge into a collecting trough below. The weir has to be extremely smooth and level, so that the water flows evenly over its entire length without creating an obvious waterfall.

Even with very careful construction though, the effect works best when the pool isn't busy. Lots of people getting in and out will change the water level faster than the pumps can compensate. It's much better to sit back, relax and enjoy the view.



The tiny lettering and details make banknotes much harder to scan and photocopy

**M**aking money

In the United Kingdom, coins are produced at the Royal Mint factory in Llantrisant, South Wales. The modern 1p, 2p, 5p and 10p coins are made of steel and plated with either copper or nickel. 20p and 50p coins, and the middle of the £2 coin, use a more expensive alloy of copper and nickel all the way through, while the 'gold' of £1 coins and the border of £2 coins is actually a nickel-brass alloy. The Royal Mint creates its own metal blanks using machines that can cut 10,000 blank coins a minute. These are fitted

with a rim and then stamped with 60 tons of force to print the design on each side!

The paper for banknotes comes from a company that specialises in high security paper. Cotton fibres and linen rag are broken down and reformed into huge rolls of paper with the watermark and metal security thread already woven through it. The notes are then printed using a mixture of colours and UV inks and with a printing process that leaves tiny raised ridges of ink.

# How are products tested?

The checks put in place to make sure your gadgets are safe

**B**efore any new product can hit the shelves, it is put through rigorous tests to ensure it is robust and safe enough to be used by the public. These tests are carried out by professional product testers, who must determine whether the product complies with the international standards set by industry experts from all over the world.

"These standards are considered state of the art when it comes to product safety," says Greg Childs, product tester in the Consumer Products and Electrical department at the British Standards Institution (BSI). "For electrical products they focus on things like protection against electric shocks and resistance to fire, making sure plastics won't catch fire very easily."

The job involves testing the products in extreme conditions, such as very hot and cold climates, as well as pushing them to their usage limits. "We test for faults that could foreseeably happen in normal use, and check that if they do happen, the product is still going to be safe to use," says Childs. "For things like washing machines, we test the product with abnormal loads. I'm sure everyone's shoved too much

washing in the machine at some point. We make sure that it wouldn't cause an issue."

The huge range of products that pass through the lab means that life as a product tester is extremely varied. From smartphones and drones to fridges and ovens, each product has its own set of tests to pass. "The standards are fairly generic for a product category, but every product is slightly different, so the most challenging bit is applying tests when they're not made specifically for the bit of kit that you're testing," he explains. "Plus, attitudes to what we consider safe change, so the standards are reviewed and reissued all the time."

As well as determining the safety of the products, the testers must also ensure they keep themselves safe should a fault be discovered. "The nature of what we do means there's always a possibility that something might go wrong, because that's what we're testing for," he says. "It's important to have the right controls in place, wear the correct safety clothing and know general electrical safety. We always make sure we have fire extinguishers nearby."



A variety of machines are used to test products to the limits

## Three typical tests your home products must pass

### 1 Environmental extremes

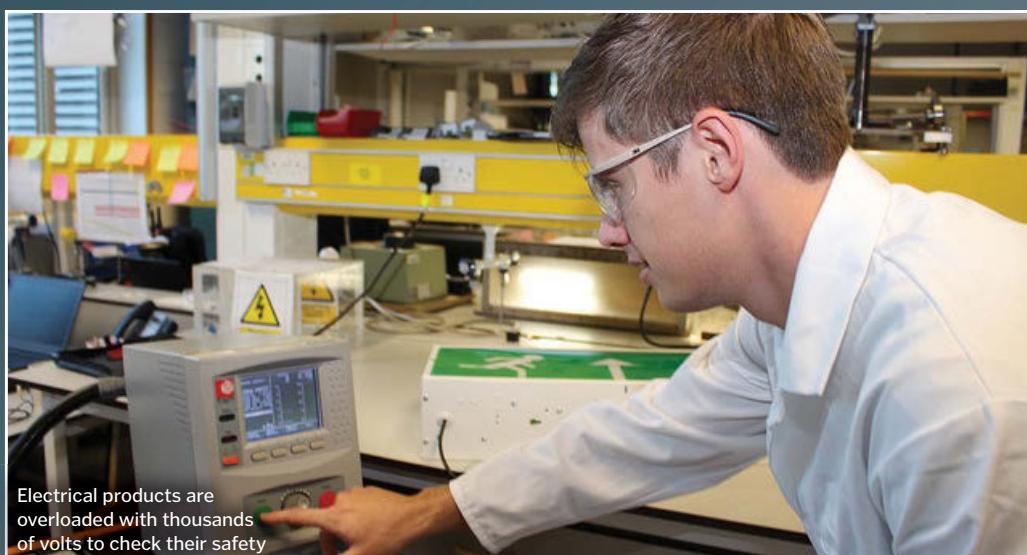
Products are often tested in climatic chambers. These are rooms where the temperature and humidity can be carefully controlled, to ensure the products will function safely in hot and cold climates.

### 2 Predicting mistakes

One test for microwaves involves sticking a metal spike through a potato and cooking it to check that it would be safe if someone did accidentally put metal in the device.

### 3 Pushing the limits

High-voltage dielectric strength testers are used to apply thousands of volts to a product to make sure that it can withstand a surge to the mains electricity supply.



Electrical products are overloaded with thousands of volts to check their safety



Cooking metal in the microwave is one of the more bizarre tasks of a product tester



# Inkjet printers

How these devices produce documents and photos with microscopic precision

**A**n inkjet printer is really just a collection of motors, rollers and drive belts that move the paper around. Almost all of the complicated technology is in the print heads. These can either be fixed within the printer, or incorporated in the replaceable ink cartridge. A single print head contains hundreds or even thousands of microscopic nozzles, each one about ten times thinner than a human hair.

These nozzles are far too thin to be made from ordinary piping. Instead, tiny channels are etched directly into the same material used to make the circuitry that fires the ink droplets. Thermal inkjet printers incorporate tiny resistive heater elements about 15 microns (thousandths of a millimetre) across. To fire the ink, the heater is switched on for a millionth of a second and the ink right next to it instantly boils. This results in a steam bubble that expands and creates a pressure wave, which then flicks a droplet of ink out of the nozzle. Inkjet printers made by Canon, Hewlett-Packard and Lexmark all use this thermal technology, but Epson and Brother printers create a pressure wave in the nozzle by applying an electric charge to special piezoelectric crystals.

Each droplet contains just a few trillionths of a litre of ink and the printer can fire out tens of

thousands of droplets per second. Most printers have four different colour inks: black, cyan, magenta and yellow, and some models also have cartridges for light cyan, light magenta, light yellow and light grey. These colours are layered on top of each other to create every possible shade. A single colour dot on the page might contain 32 separate ink droplets and high-quality printers can produce millions of dots in every square centimetre.

## From printer to page

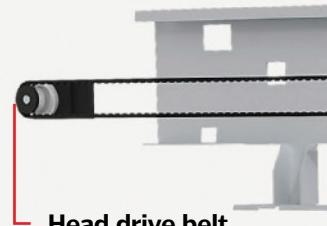
Each component executes a precisely choreographed dance to get the ink to the right spot



Heavy-duty commercial inkjet printers can produce 75,000 pages from a single cartridge.

### Feed rollers

The rollers that guide the paper on its journey through the printer are linked together to prevent slipping or tearing.



### Head drive belt

A stepper motor drives this belt left and right to position the print head on the page.



### Ink-credible prices

Printer manufacturers have been accused of driving up the cost of ink cartridges in recent years, by surreptitiously reducing the amount of ink in each one. A typical combined colour/black cartridge contains just 16 millilitres of ink, compared with 42 millilitres in 2003, and costs the same £20-£25. That works out at around £1,250-£1,500 per litre, which is roughly as expensive as Chanel No. 5 perfume. However, advances in printer technology mean that they waste less ink and you can still expect around 250 pages from a single cartridge. The cost of the printers themselves has also fallen, because manufacturers sell them almost at cost price, and make all their profit from the ink cartridges.

### Paper tray

Adjustable guides on either side ensure that the stack of paper is always perfectly centred for the feed roller.



### Print head

A matrix of tiny nozzles squirts a cloud of ink droplets, flying in formation to make a precise pattern on the paper.

### Print cartridge

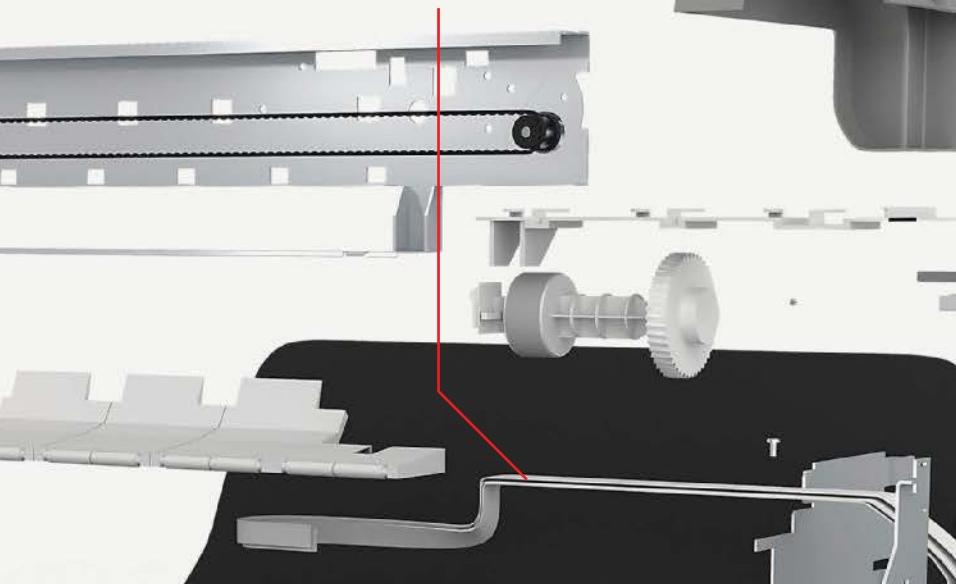
Each of the ink colours is held in its own reservoir with a dedicated print head. Some printers combine the colour cartridges into one unit.



"A single print head contains hundreds of microscopic nozzles, each one about ten times thinner than a human hair"

**Ribbon cables**

Separate signal wires for each print head control the precise timing of each nozzle squirt.



## Clog-free colours

Printer ink needs to dry quickly once it hits the paper, but if the ink dries in the nozzles then they will clog. When the printer isn't in use, the print heads are sealed with a rubber cap to keep them from drying out but during printing, individual nozzles might be uncovered for a long time, even though that particular colour isn't needed. To help keep them flowing freely, the print head deliberately scans past the edge of the paper and fires the unused nozzles into a small chamber, like the printing equivalent of a Wild West spittoon. It wastes a little ink, but much less than running a full cleaning cycle. Some printers will pause to wipe the print head against a rubber squeegee to clean off any crusted ink. This is often what is happening if the printer makes those strange clanking and whirring sounds when idle.

The individual ink dots on a page are visible under high magnification



**Output tray**

Printed pages are given enough time to dry before they are stacked together.



**Code strip**

This is a clear plastic strip with a dense pattern of black lines. A detector on the print head uses this to check its alignment.



**Paper pickup roller**

A rubber cam rotates to grip the top sheet in the paper tray and feed it into the printer.

**Controller board**

Raw image information from the computer is converted to the signals that move and fire the print heads.

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# Food blenders

Turn fruit salad into smoothie with a tornado in a jar

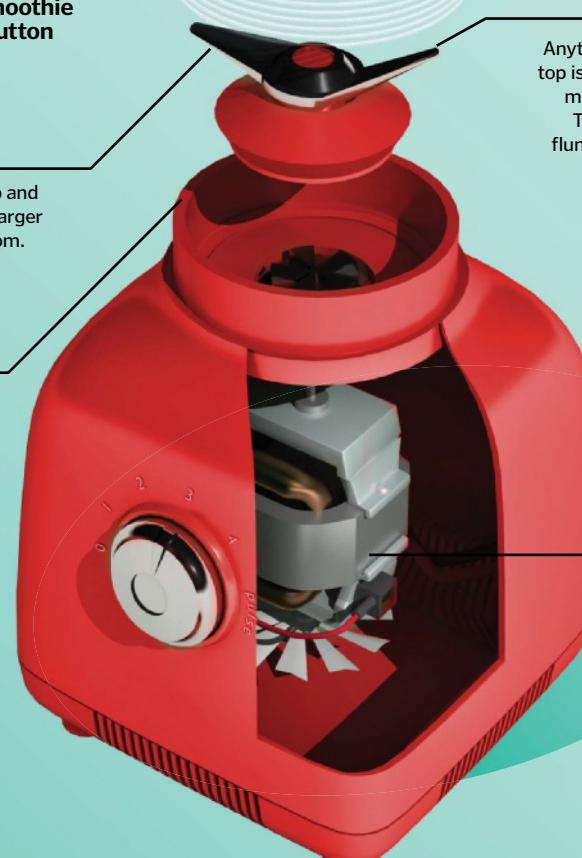
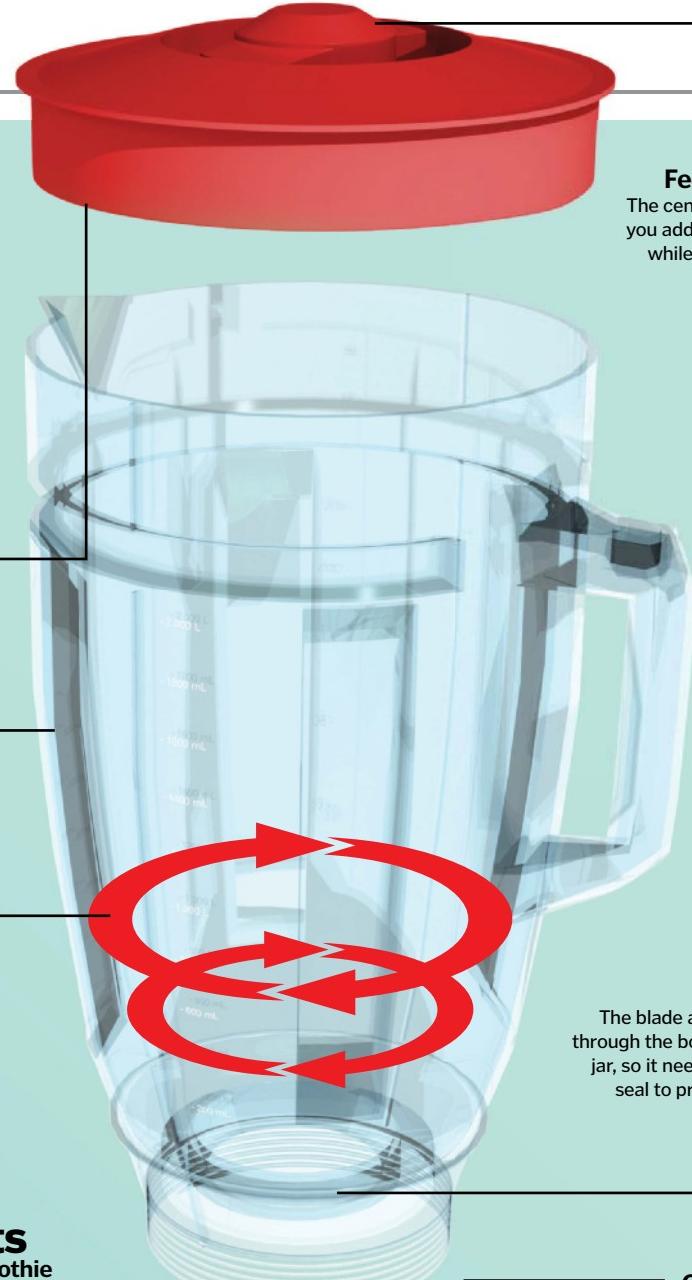
A smoothie blender is a compact fluid dynamics laboratory. Friction at the surface of the blades accelerates the liquid, centrifugal force pushes it outwards, atmospheric pressure creates an air-filled vortex in the centre, and turbulence keeps everything churning and mixing. Within seconds, your placid pint of milk and fruit chunks is transformed into a chaotic, churning maelstrom.

The vortex in the centre of a blender looks like a tornado but it acts in quite a different way. A tornado is powered by a thermal updraft in its centre that pulls everything into the middle and flings it up to the sky. In a blender, the spinning blades at the bottom are constantly pushing the liquid away from the middle to the edges of the jar and this creates a suction that pulls material downwards in the centre.

The cutting blades do most of the initial work of chopping up the solid chunks, but once the size of the pieces drops below a certain point, the blades can't hit hard enough to slice them up any smaller. Amazingly, the blender uses implosion shock waves to finish the job. The blades are spinning so fast that they create a vacuum on their trailing edge. The water caught in their wake effectively boils, and as the tiny steam bubbles condense and collapse again, they send out a cascade of shock waves that shatter the food particles even further.



Don't forget to put the lid on!



**Feeder cap**  
The centre hole lets you add ingredients while the blender is running.

**Lid**  
The vortex forces the liquid up the sides of the jar, so a tightly sealed lid is vital.

**Jar**  
The funnel shape helps pull the liquid up from the bottom with no stagnant spots.

**Rotating**  
The spinning blades drag the liquid round with them and centrifugal force tends to push it out towards the edge and up the sides of the jar. This pushes the surface up at the edges and down in the middle.

**Blender bits**  
From chunky to smoothie at the touch of a button

**Blades**  
Angling some blades up and others down creates a larger slicing zone at the bottom.

**Coupling**  
A cog arrangement connects to the blade axle and locks the jar in place.

**Seal**  
The blade axle extends through the bottom of the jar, so it needs a reliable seal to prevent leaks.

**Chopping**  
Anything solid dropped in at the top is pulled downwards into the middle until it hits the blades. The shredded fragments are flung back to the top again and with every circuit, they are chopped a little bit finer.

**Motor**  
The motor is powerful enough to slice through tough greens, and a weight at the bottom helps keep the blender steady too.

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**8 million tons**

The amount of plastic waste that enters the ocean each year

**1 trillion**

The number of plastic bags used each year worldwide

**100 kilograms**

The average amount of food thrown away every year per person in the UK - over half of which is perfectly edible!

**100,000**

The number of marine mammal deaths caused by plastic debris each year

# How to **SAVE** the WORLD

Discover the incredible science and tech that will protect our planet

**90%**

Proportion of the world's seabirds estimated to have ingested plastic, including bags and bottle tops

**75,000**

The number of trees that would be saved by recycling just a single run of the Sunday New York Times

**15-30%**

The proportion of childhood asthma cases that are thought to be triggered by air pollution

**H**umans only make up about one ten thousandth of the biomass on Earth, but our impact on the planet is drastically out of proportion to our numbers. In the last 250 years we have added over 400 billion tons of carbon to the atmosphere and approximately half of that has happened since the mid-1980s. No other organism in Earth's history has altered the environment so much so quickly.

It's not just the amount of pollution we produce either; humans have invented entirely new kinds of pollution too. Polythene, chlorofluorocarbons, organophosphates and synthetic hormones didn't exist in the environment until humans created them. Other toxins, like heavy metals and radioactive isotopes, were only there in trace amounts until the industrial age found new ways to refine and concentrate them. These pollutants are toxic because they are too new for life to have evolved a way of dealing with them, which means they don't get broken down either.

A 2007 study found more than 24 synthetic chemicals and pesticides in wild salmon – and non-toxic pollutants can be just as harmful. Fertilisers that run off the land into rivers can cause such a sudden explosion of algae that waterways are blocked with green slime. When this dies and decays, the surge in bacteria depletes the water of oxygen and kills off the fish.

But pollution is entirely within our power to control. In 1952, the Great Smog of London killed an estimated 12,000 people over four days, but four years later the Clean Air Act was passed and air quality steadily improved. The countries that were once the biggest polluters have also been the first to introduce emissions standards. Just 50 years ago, New York City was plagued by a dense smog responsible for around 24 deaths per day, but air pollution legislation and incentives have helped to drastically improve the city's air quality. The Big Apple is even working towards achieving the cleanest air of any major US city by the year 2030.

The technological progress that created the pollution can also be harnessed to curb it. Cleaner fuels, more efficient engines, better recycling, and environmental clean-up technologies are all being developed to slow the rate at which humans are poisoning the planet. From huge, garbage-sucking machines in the ocean to neighbourhood recycling schemes, there is a way for everyone to help ensure that Earth's most polluted century is behind us.

#### Pump liquid CO<sub>2</sub> into deep sea

CO<sub>2</sub> could be liquified under pressure from industrial exhaust gas, and pumped into deep ocean waters, where it would remain dissolved.

# Can we stop global warming?

While governments squabble over carbon emissions, innovative technology could help to slow temperature rises

#### Ozone preservation

Halting the use of CFCs, HCFCs and halon products preserves the ozone layer that shields us from the Sun's UV rays.

#### Cloud seeding

Injecting the atmosphere with tiny particles for water vapour to condense on encourages clouds to form. Bright clouds help cool the planet by reflecting more sunlight.

#### Giant reflectors in orbit

A giant space mirror could lower Earth's temperature by as much as three degrees Celsius.

#### Stratospheric aerosol release

We could shield Earth by replicating the effects of big volcanic eruptions, sending aerosols high into the stratosphere.

#### Genetically engineered crops

Nitrous oxide is a greenhouse gas 296 times more potent than CO<sub>2</sub>. GM crops need less fertiliser, which reduces nitrous oxide emissions.

#### Reforestation

Vegetation is a vast engine for carbon dioxide turnover – taking in CO<sub>2</sub> (and other gases) and pumping out oxygen.

#### Greening deserts

An increase in vegetation allows more carbon dioxide to be taken up, and reduces the amount of heat reflected from the ground back into the atmosphere.

#### Iron fertilisation

This encourages algal blooms, which draw CO<sub>2</sub> into the upper strata of ocean, and form the base of the entire food chain.

#### Pump liquid CO<sub>2</sub> into rocks

Ocean storage of CO<sub>2</sub> would eventually acidify the ocean, so a more feasible idea is to store it in porous rock strata underground.



# Ground pollution

The toxic chemicals lurking beneath the surface of our poisoned planet

Land pollution isn't just about the space taken up by landfill. A city the size of New York could fit all of its rubbish for the next thousand years in a landfill 56 kilometres long by 56 kilometres wide. That sounds like a lot, but that's the waste of 2.5 per cent of Americans buried in just 0.03 per cent of the country's land area. And that land isn't gone forever – eventually a landfill site just becomes a grassy hill.

The real source of land pollution is all the other things that don't end up in landfill. Copper and aluminium mining generate huge piles of powdered rock (called 'tailings') left behind after the metal has been extracted. These tailings are high in toxic heavy metals, such as mercury and cadmium, and aluminium mining alone generates 77 million tons of tailings worldwide every year.

Modern farming also requires more than just sunshine and rain. In the UK, farmers add an average of 100 kilograms of nitrogen fertiliser to every hectare of arable land and grassland each year. Whatever the crops don't absorb gets washed into the groundwater and ends up in our rivers, going from land to water pollution.

The low-tech solutions to land pollution are the three Rs: reduce, reuse, recycle, and these are in decreasing order of effectiveness. Reducing the amount of cardboard or cabbage you need to buy in the first place has a much bigger impact than simply recycling all the leftovers, because it also saves the energy that would have been required to process and transport them to you, and then collect and recycle them again afterwards.

But there are high-tech pollution solutions as well. Bioremediation uses selected strains of

Waste from construction sites can be recycled at specialised plants

naturally occurring organisms to break down contaminants in the soil. Wood fungi for example have been shown to break down the toxins in oil spills and also certain chlorine pesticides. Heavy metals like cadmium and lead can't be broken down, but certain plants will take them up through their roots and store them in their leaves or stems. This technique, which is known as phytoremediation, uses plants to soak pollutants from the ground so that they can be removed more easily. Chinese brake fern can even filter out arsenic in this way.



## Inside a single-stream recycling plant

The machine that separates your recyclables so you don't have to

### 1 Tipping floor

A steady stream of recycling collection vehicles arrives at the facility, dumping their cargo of mixed recyclables out onto the tipping floor. Drivers look out for any oversized objects like car engines that would cause damage to the plant machines.

### 2 Loading

Powerful loaders shunt piles of assorted recyclables into a large hopper, where they are tumbled over a rotating drum to loosen compacted materials. They then flow onto a giant conveyer belt, which whisk the jumble into the main facility.

### 3 Manual pre-sort

Teams of human sorters pick out non-recyclable items from the fast-moving stream, including crisp packets, plastic bags, shoes and nappies, as well as large items like scrap metal that might jam the machines.

### 4 Star screen sorting

A series of vibrating, rotating shafts, fitted with offset star-shaped discs, lift large and light materials like cardboard upwards; smaller items like paper, bottles and cans fall through and continue on the conveyer belt.

### 5 Manual sort

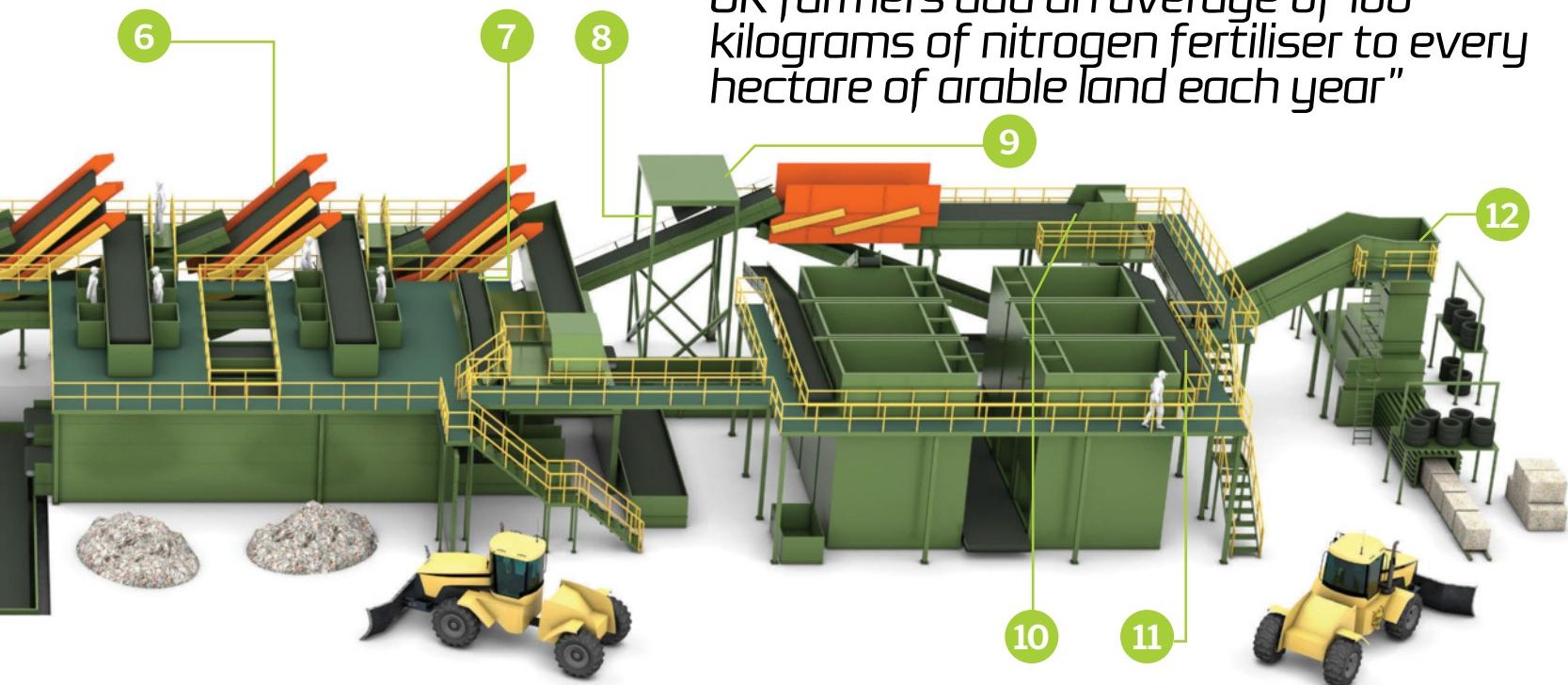
For a second time, teams of human sorters stand at intervals along the conveyer belt and look out for any smaller contaminants that might have snuck into the mix, such as personal electronics, trinkets, wallets and pieces of food.

### 6 Star screens round two

A trio of finer-grained star screens sift out different grades of paper, which are directed towards dedicated storage units. Glass, metals and plastics fall through the screens again and continue on the conveyer belt.



"UK farmers add an average of 100 kilograms of nitrogen fertiliser to every hectare of arable land each year"



### 7 Glass sorter

As they fall through the star screens, glass containers get crushed by the rotating stars. The fragments fall into bins below the screens, and are transported offsite to be sorted by colour and ground into coarse sand.

### 8 Steel magnet

The remaining materials pass under a powerful rotating belt magnet, which lifts out tin and steel cans and drops them into a storage bunker. This usually only removes around four per cent of the recyclables passing through the plant.

### 9 Eddy current separator

Since aluminium isn't magnetic, it is picked out using a strong reverse magnet called an eddy current separator. This uses spinning magnets to induce a current in the cans, which makes them fly off the belt and into a bunker.

### 10 Optical sorting with IR lasers

Computerised scanners use infrared lasers to identify certain plastics by their optical properties. Once identified, an item will be thrust into a specific bunker by a directional burst of air.

### 11 Manual sorting

The remaining plastics are carefully sorted by teams of workers. They also perform a last check, picking out and redirecting any recyclable items that have been missed by the mechanical processes and remain on the line.

### 12 Baler

One at a time, the bunkers are opened, pouring out plastic, cans, metals or paper. Baling machines compress these into cubic bales ready to be taken to reprocessing plants for recycling. Any leftover materials at this point go to a landfill site.



# Air pollution

With the potential to cross international boundaries, air pollution is a truly global problem

Air pollution is the introduction of gases and particles into the atmosphere that have harmful effects on living creatures and the built environment. According to the World Health Organisation, 7 million premature deaths are caused every year by people inhaling polluted air – that's one in eight deaths worldwide. Once released into the atmosphere, pollutants are impossible to contain and – depending on prevailing weather patterns – have the potential to affect people who are hundreds or even thousands of kilometres from the source.

Over the last half century, the nature of the problem has altered. In the developed world, smog-causing emissions of noxious smoke, sulphur dioxide and particulates associated with incomplete fuel combustion have been curbed by technologies like flue-gas desulphurisation

systems, soot scrubbers and catalytic converters. Gases that deplete the stratospheric ozone layer most aggressively have been outlawed and replaced by safer compounds, and today it's the threat of global warming that looms largest.

There is growing evidence, however, that respiratory problems like asthma might actually be caused by air pollution, not just triggered by it. Some researchers have even made tentative links between neighbourhood air quality and rates of childhood autism.

As with other forms of pollution, the best way to protect the environment is to avoid releasing these toxic elements in the first place. Conserving electricity, driving mindfully, and choosing to walk, cycle or take public transport are easy choices we can all make in order to breathe a little easier.



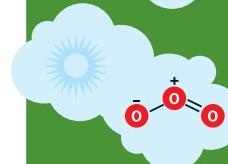
## Atmospheric pollutants

The major contributors to environmental damage



### Carbon monoxide (CO)

This gas is produced when fossil fuels burn incompletely, with road vehicles being the predominant source.



### Ozone (O<sub>3</sub>)

This is formed when other pollutants react in the presence of heat and sunlight. It triggers lung irritation and asthma attacks.



### Nitrogen oxides (NO<sub>x</sub>)

These form during fossil fuel combustion and contribute to global warming, smog and ground level ozone formation.



### Volatile Organic Compounds (VOCs)

In the presence of pollutants, these carbon-based chemicals contribute to the formation of ground level ozone and smog.



### Sulphur dioxide (SO<sub>2</sub>)

This is produced during incomplete combustion in coal-fired power stations and fireplaces. It contributes to smog and acid rain.



### Particulates

These include airborne dust, dirt, soot and smoke. They can cause respiratory problems and environmental damage, such as acidification of lakes.

## Photocatalysis

In some cases, airborne pollutants convert to harmless materials when they react chemically with other atmospheric gases. These reactions happen naturally in the presence of light, but on a slow timescale. In photocatalysis, the rate of these everyday reactions is boosted using a catalyst.

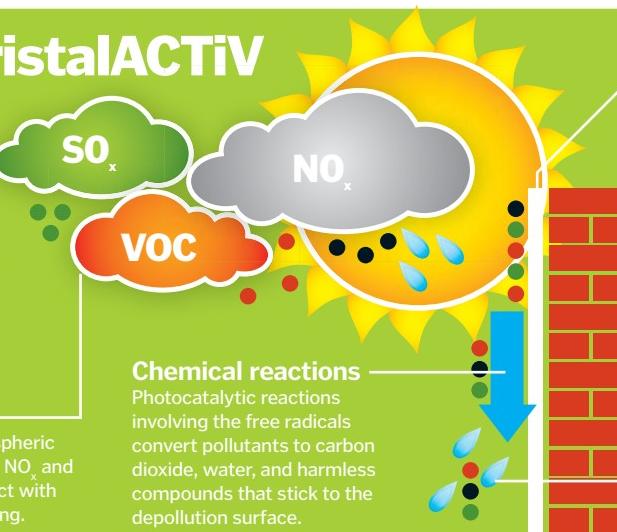
Innovative chemical company Cristal has pioneered a pollution-busting coating that can be painted directly onto buildings. Made from ultra-fine photocatalytic titanium dioxide ( $TiO_2$ ), it actively draws pollutants including VOCs,  $NO_x$  and sulphur dioxides from the surrounding air and converts them into harmless by-products that are easily washed away. Best of all, the catalyst itself is not used up in the reaction, so its performance never dips.

## How CristalACTiV works

This clever coating can be painted on structures to help cleanse the surrounding air

### Pollutants

Photoreactive atmospheric pollutants like VOCs,  $NO_x$  and  $SO_x$  come into contact with the depollution coating.



### Depollution coating

Under the sun's UV light, the titanium dioxide ( $TiO_2$ ) coating forms highly reactive free radical particles, capable of breaking down pollutants.

### Self-cleaning surface

The soiled surface is washed clean whenever rain falls, or it is hosed down.

# Ocean pollution

From oil and debris to sewage and toxic chemicals – our seas have it all

Oceans cover 71 per cent of our planet's surface and contain an estimated 1.5 million species, but that hasn't stopped humanity treating the sea as a giant, watery rubbish bin.

We're familiar with tragic images of seabirds whose feathers are clogged with viscous black oil. But catastrophic spills from tankers account for just a fraction of oil pollution in the sea; street runoff, vehicle exhausts and industrial waste are all chronic contributors to the problem.

Indeed, almost all marine pollution stems from activities on land. Runoff from farms introduces pesticides and insecticides into the aquatic food chain, as well as an overabundance of nutrients in the form of fertiliser. This causes populations of algae to spike, draining the surrounding waters of oxygen and suffocating other marine life.

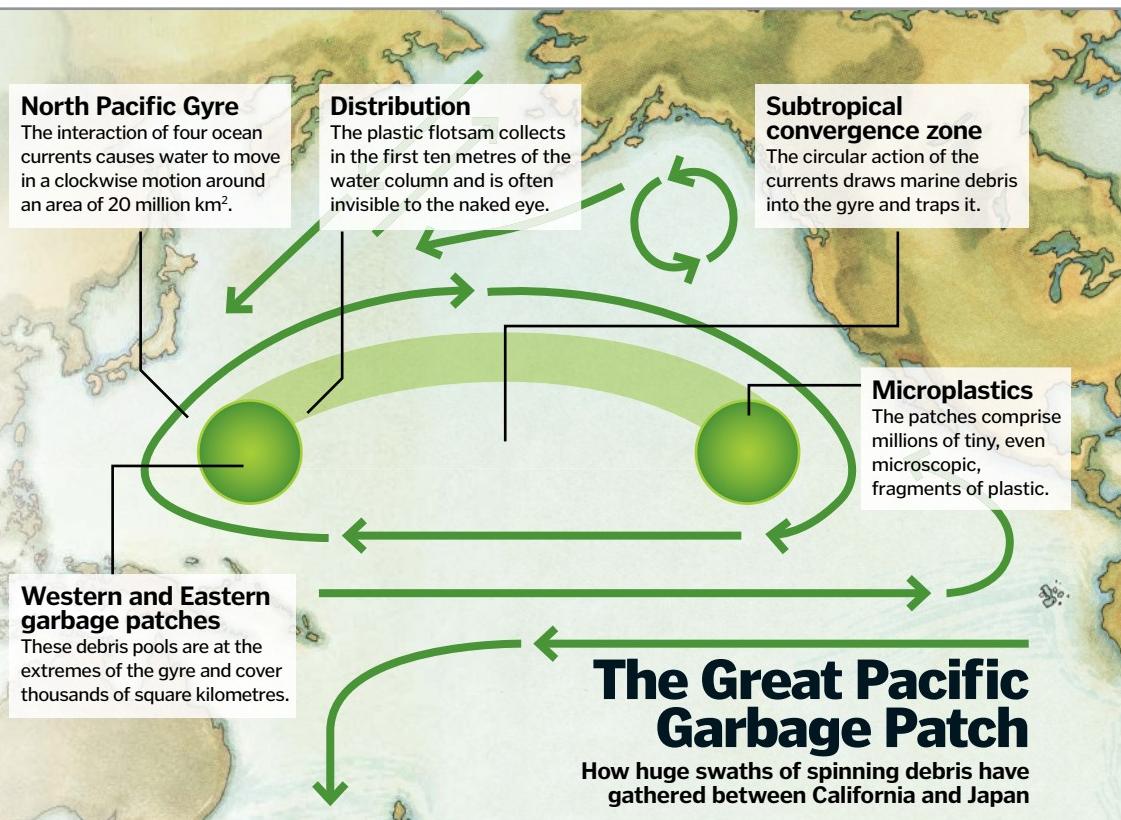
Finally, human-made rubbish is ubiquitous throughout the world's oceans, where it is corralled by currents into vast swirling 'garbage patches'. Many items, including fishing gear, glass, metal, paper, cloth and rubber, can take years, decades, or even centuries to decompose.

The worst offenders – plastics – essentially persist forever, but are broken down under the Sun's UV rays into ever smaller pieces. The eventual soup of 'microplastics' – invisible to the naked eye – poses a threat to wildlife that ingests it, and to the entire food chain due to the leaching of harmful chemicals.

**"Almost all marine pollution stems from activities on land"**

There are no easy solutions, but a burst of new technologies may begin to turn the tide. In just 18 months, 'Mr Trash Wheel', a filtering water wheel with its own Twitter account, has removed over 400 tons of rubbish from Inner Harbor in Baltimore, US. Proposals for open ocean filtration systems include a solar-powered 'vacuum boat' called SeaVax, that its inventors claim will suck up 22,000 tons of garbage each year.

The most common items washed up on beaches include plastic bottles and cutlery, and coffee cup lids. The good news is that means we can help by making simple changes to our lifestyles, like carrying reusable water bottles and utensils.



## Marine debris timeline

How long does common rubbish persist in the ocean?



### Cigarette butt

The most common item found on beach clean-ups, making up 25 per cent of all collected debris. They contain a synthetic fibre that takes years to break down.

### The Ocean Cleanup Array

The brainchild of 21-year-old Dutch inventor Boyan Slat, the Ocean Cleanup Array harnesses ocean currents to sweep floating plastic debris into a gigantic 100-kilometre long collector for recycling. The innovative system comprises a pair of floating barriers, held in a V-shape, that skim tiny pieces of plastic flotsam from the oncoming currents while allowing sea life to pass safely underneath.

The crowdfunded project – now at the model testing stage – has the potential to remove over 7 million tons of microplastics from the world's oceans, and its creators claim that a single Ocean Cleanup Array could halve the size of the Great Pacific Garbage Patch in just ten years.

### Booms

Floating storm-resistant barriers, stretching out over 100 kilometres, are moored to the sea bed.

### Natural funnel

The barriers are placed in a V-shape around a central platform, causing the trapped debris to gradually drift inwards.

### Central platform

This extracts the concentrated mass of microplastics and stores it for transport to recycling facilities.

### The motion of the ocean

Ocean currents carry plastic into the barriers, and debris begins to build up behind them.



# Venus flytrap

Insects don't stand a chance when they land on this killer plant

The carnivorous Venus flytrap sports a menacing-looking mechanism. The spiked, collapsible leaf is laced with drops of sweet nectar to lure in its insect prey.

When a bug lands, it touches the sensitive trigger hairs on the Venus flytrap's leaves. According to the latest theory, touching one hair does nothing, but touching two causes the trap to snap closed. When the fly struggles, it's likely to trigger three hairs, which readies the plant's cells for digestion, and touching five hairs starts the release of digestive enzymes. The plant can even adjust the amount of digestive fluid produced, depending on how large the prey is.

Exactly how these bug-catching plants manage to snap shut so quickly is not fully understood. However, research suggests that it is related to very sudden pressure changes within cells in the trap's leaves. When the Venus flytrap is open, the leaf tissue is held under tension. When an insect lands on the trap and triggers the hairs, this tension is released and the leaves close in a fraction of a second. The large guard hairs fold together, depriving the insect of any means of escape. The digestive fluids break down the soft parts of the prey and absorb the nutrients. Five to 12 days after capture, the trap will reopen to expel the waste exoskeleton.

## Trigger bristles

When a fly lands, sensitive hairs on the inside of the leaf trigger the trap.

## Digestive glands

Spots inside the leaf secrete digestive fluids and absorb nutrients from the prey.

## Marginal spines

These protrusions of the leaf prevent the prey from escaping the trap.

A trap will catch three to five meals before photosynthesising for around three months and dropping off the plant



## Nectar

The leaves secrete a sweet nectar to lure in its unsuspecting prey, typically insects and spiders.

# Canada's Spotted Lake

Nestled in a mountainous, forested landscape is a masterpiece of nature

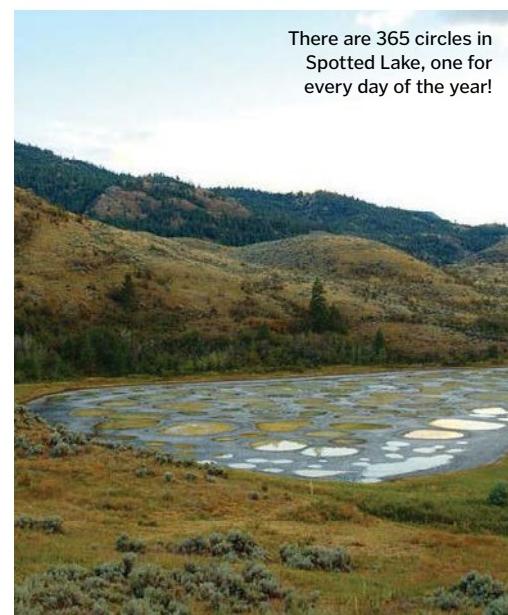
Near the town of Osoyoos, in Canada's British Columbia, lies a lake covered in large, round patches that look as if they have been drawn on by hand. This amazing natural phenomenon appears every summer when scorching temperatures cause the shallow water of the lake to evaporate.

Covering an area of around 16 hectares, the patches that give Spotted Lake its name are actually pools of rich minerals, including calcium, sodium sulphates and magnesium sulphate, as well as traces of silver and titanium. Hues of green and blue decorate the landscape,

and throughout the summer the spots change colour and shape as the minerals adapt to further evaporation. When the fresh water disappears, the bed of the lake is exposed, providing natural walkways through the mineral-rich pools.

However, walking through the Spotted Lake pools isn't a possibility for visitors, as it's owned by the Okanagan Nation. To the native community of the Okanagan Valley, the lake is known as 'Kliluk' and holds special spiritual and historical significance. It was bought back from a private owner in 2001 so that it could be protected from development.

There are 365 circles in Spotted Lake, one for every day of the year!



© Getty

# Life cycle of a frog

Discover how a cluster of cells transforms into a hopping, croaking amphibian

The cycle begins when frogs mate. The male holds the female in a position known as amplexus and fertilises her eggs as they are laid. A female frog can lay a clutch of around 3,000 to 6,000 eggs.

Within each jelly-like sphere is a black dot – the developing tadpole. The embryos feed off the surrounding jelly as they grow, and then once they have developed rudimentary gills and

a tail after about a week or a month (depending on the species), tadpoles hatch. The hatchlings feed on the rest of the frogspawn jelly mass, as well as any algae that has grown on it.

Throughout the next few weeks the tadpoles undergo a fast metamorphosis. First their external gills disappear, replaced by internal gills, which in turn are replaced as lungs develop. The tadpoles also grow legs while they

turn into froglets – strange round critters that resemble their adult form, while still retaining their powerful tail. The front legs are the last to develop, and the tadpole's tail is shortened as it is reabsorbed into the body.

The little frog is now a miniature version of its parents at just one centimetre in length. After around 16 weeks of development it can leave the water, breathe air and feed on bugs and insects.



## 1 Amplexus

The male positions himself behind his mate and holds her firmly with his front legs.

## 2 Spawning

During spawning the female lays her eggs, which are then fertilised by the male.

## 3 Eggs

Frogspawn is buoyant, and large clumps of the gelatinous egg mass can be seen floating on a pond's surface.

## 4 Tadpole

After a few weeks, the small tadpoles hatch with external gills and long tails.

## 5 Froglets

As the tadpole grows, it develops a strong tail as well as powerful back legs.

## 6 Metamorphosis

In several stages, the tadpole grows adult eyes and front legs and loses its tail.

## 7 Adult frogs

The young frog continues growing once it leaves the water. After around three years it is ready to reproduce.

Tadpoles are often seen in large groups, sometimes called 'clouds'



# A TRAVELLER'S GUIDE TO THE SOLAR SYSTEM

Join us as we embark on an epic voyage to the must-see sights

Today, space travel is the reserve of multibillion dollar national space agencies and private companies. But in the not too distant future, it may become much more accessible and even affordable to the average person. In this future, it's unlikely space travel will have changed too much, barring a major breakthrough. Astronauts will probably still launch into space on rockets, or maybe spaceplanes, and journeys around the Solar System will still rely on using gravitational

assists from other planets to reach far-flung destinations. But some dreamers imagine that we might have large habitats traversing the Solar System, which would-be space tourists could hitch a ride on to visit cosmic destinations.

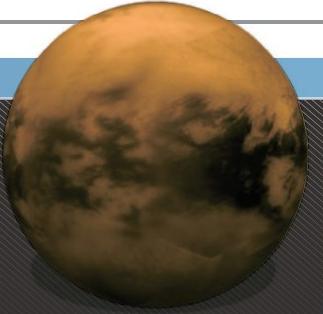
There's certainly no shortage of fascinating places waiting to be explored. Relatively nearby, both Mars and Venus possess features that make them almost Earth-like – and others that make them certainly not. Further out, some of the icy moons of Jupiter and Saturn may have

huge underground oceans that could harbour some form of primitive life, while Jupiter itself is fascinating – with a giant storm in its atmosphere that has raged for four centuries.

What would it be like if such destinations were within reach of the average person? Perhaps, as you'll see over the next few pages, we would have tourist brochures describing some of the fantastic holidays you could venture on. So join us as we step into the future to see what the vacations of tomorrow might look like.

# TITAN

An Earth-like alien world



MERCURY  
VENUS  
EARTH  
MARS  
JUPITER  
SATURN  
URANUS  
NEPTUNE

Journey time: **Six years**  
 Nearby destinations:  
**Saturn, Enceladus, Mimas**  
 Average temperature:  
**-180 degrees Celsius**

Tired of Earth's poisoned waters and polluted skies? Why not come and see the only other world with lakes and seas on its surface? On Saturn's moon Titan, you'll see oozing bodies of liquid methane as they shimmer on the surface. The largest sea, Kraken Mare, covers 400,000 square kilometres – more than the Caspian Sea here on Earth. It's so thick that it almost looks solid, with the biggest waves only reaching 1.5 centimetres high. Don't fall in by mistake!

Above you, you'll be treated to the most Earth-like weather climate in the Solar System – apart from Earth, of course. On our planet, water is cycled from the ground to the atmosphere, but on Titan, there's methane rain. However, plan your trip wisely, as it only rains once every 1,000 years.

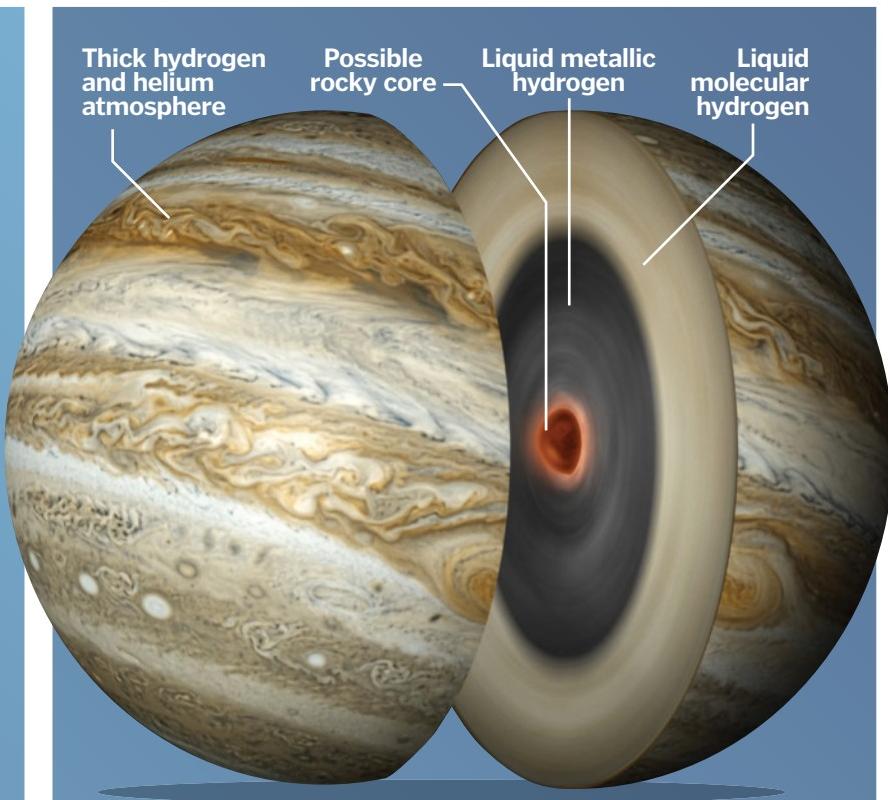
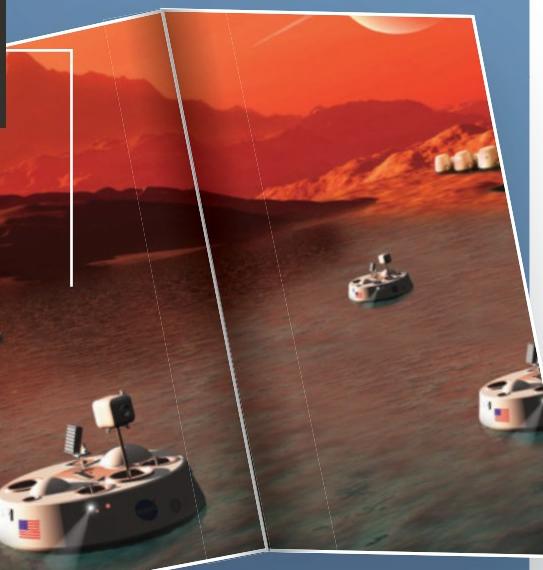
Perhaps best of all, you'll get to experience the moon's



surface. From wind-swept sand dunes to the frozen, icy plains, take your time to explore this strange and alien landscape on the trip of a lifetime. If you're lucky, you'll even get to see the first man-made spacecraft to ever touch down on the surface – the Huygens lander – which arrived back in 2005.

### Wrap up warm

Temperatures on Titan's surface fall to -180°C – look out for rocks of ice and liquid methane!



# JUPITER

Eye of the storm



MERCURY  
VENUS  
EARTH  
MARS  
JUPITER  
SATURN  
URANUS  
NEPTUNE

Journey time: **Five years**  
 Nearby destinations:  
**Europa, Ganymede, Io**  
 Average temperature:  
**-145 degrees Celsius**

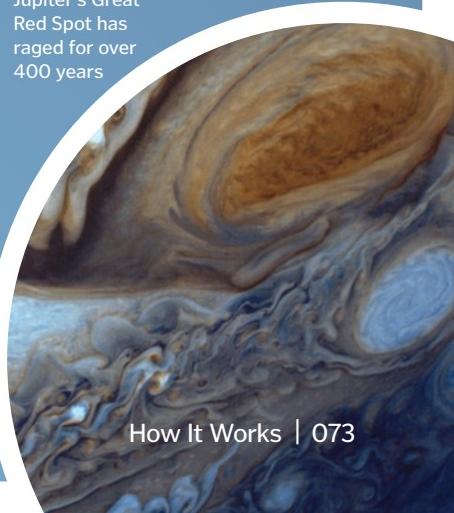
With a storm that has raged for over 400 years and lightning bigger than anything on Earth, you better book soon or miss out! Welcome to Jupiter, the largest planet in the Solar System. This gas giant has a thick atmosphere of hydrogen and helium, with a liquid metallic hydrogen core lying beneath. The pressure there is two million times stronger than the surface pressure on Earth, so you won't be leaving the spaceship – you'd be crushed before you had your complimentary cocktail.

A highlight will be the Great Red Spot, a giant anti-cyclone that has raged since the 17th century. Three Earths would fit inside the storm and the lightning is 1,000 times more forceful than that on our planet. What's more, Jupiter's powerful magnetic field creates fantastic aurorae at its poles that are bigger than the entire Earth.



Jupiter's Great Red Spot has raged for over 400 years

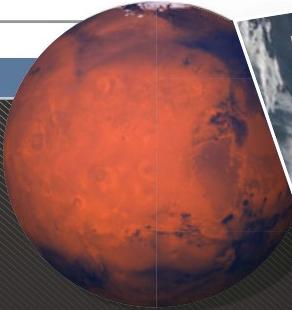
© NASA, Hubble Heritage





# MARS

Look into our future



Journey time: **Eight months**

Nearby destinations:

**Phobos, Deimos**

Average temperature:

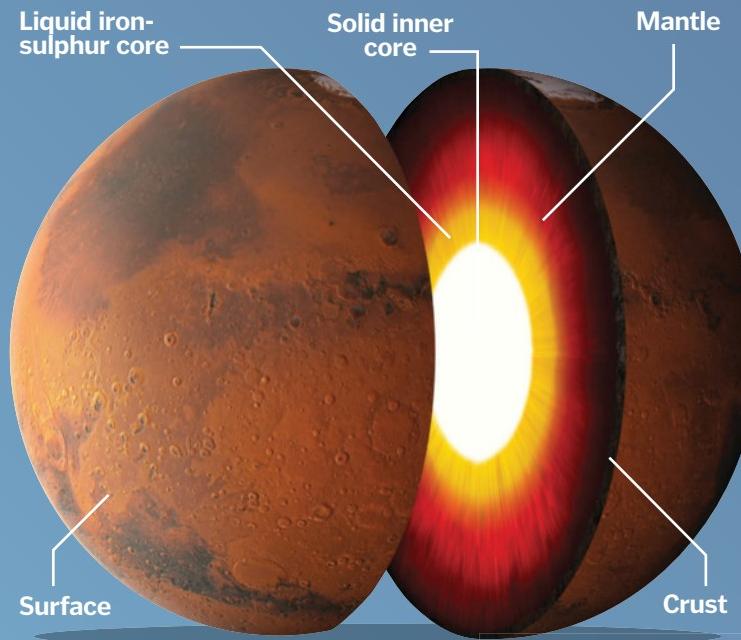
**-55 degrees Celsius**

We haven't got round to inventing time travel yet, but we've got the next best thing: a glimpse of what will become of Earth in a few billion years. This is Mars, a world that once played host to vast oceans and seas, but is now barren and dry as its atmosphere was stripped away by the Sun. On a trip to Mars, you can explore the ancient river and stream beds, remnants of a much more Earth-like past.

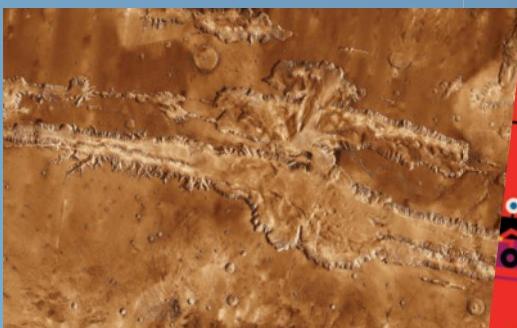
That's not all. Stretching across the equator of Mars is a

vast canyon system known as Valles Marineris. It is 4,000 kilometres long – nearly ten times the length of the Grand Canyon – making it the biggest in the Solar System.

Elsewhere on Mars, you can also visit the largest mountain, Olympus Mons. Spanning 624 kilometres in diameter, it's roughly the size of Arizona, and a towering 25 kilometres high. You'll need to bring your hiking shoes if you decide to climb this cosmic behemoth.



Valles Marineris is the biggest canyon in the Solar System



Enceladus is relatively small, as seen here compared to the United Kingdom



# ENCELADUS

A world of ice



Journey time: **Six years**

Nearby destinations:

**Saturn, Titan, Dione**

Average temperature:

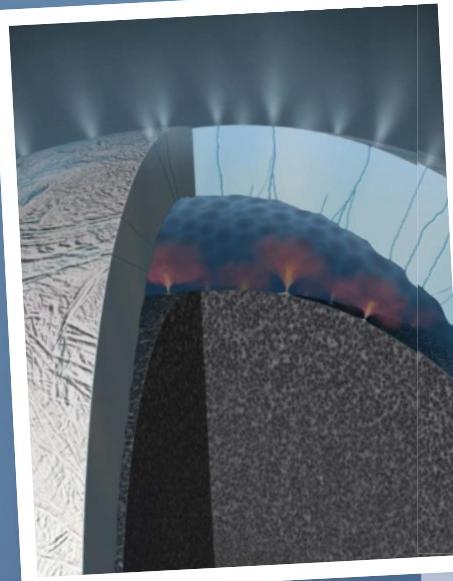
**-200 degrees Celsius**



At first glance, you might not be that impressed by Enceladus. Just 500 kilometres in diameter, it is only the sixth largest moon of Saturn, and its surface doesn't look too interesting initially. Peer a little closer, however, and you'll quickly discover a rich and fascinating world. When you arrive at Enceladus, the first thing you'll notice is how bright it is. In fact, it reflects almost all of the sunlight that hits it because the surface is made of ice. It's also dotted with vast canyons up to 200 kilometres long, shaped by tectonic activity in the moon's past.

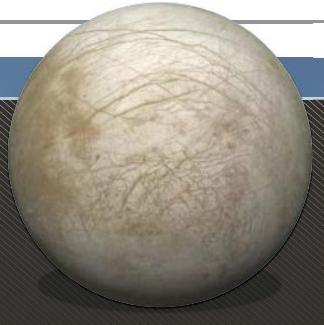
Perhaps most of interest, though, are the cryovolcanoes – which shoot ice, not lava – near the south pole that are responsible for powering hundreds of geysers. The source of water for these is a vast subsurface ocean, kept wet by the inner heat of Enceladus and tidal forces from another of Saturn's moons, Dione. Small though it may be, this moon is full of surprises. And who knows what lies beneath the surface? Some say the conditions may be right for some form of primitive life to exist.

Large geysers of water vapour fire out from the south pole of Enceladus



# EUROPA

## Search for life



Journey time: **Five years**  
Nearby destinations:  
**Jupiter, Ganymede, Io**  
Average temperature:  
**-160 degrees Celsius**

As far as we're aware, we're still alone in the universe. But one of our best bets for finding life on a world other than Earth may be Europa, the fourth largest moon of Jupiter. And you, too, could be part of an exciting discovery.

On Europa, you'll orbit Jupiter once every 3.5 days, with the same face of the moon always pointing towards the gas giant. But the orbit of Europa is elliptical, so it is pushed and pulled by the massive planet. This heats its core and, beneath the icy surface, allows a vast ocean, containing more water than there is on Earth, to exist. This source of heat, coupled with the existence of water, suggests the interior of Europa might be habitable.

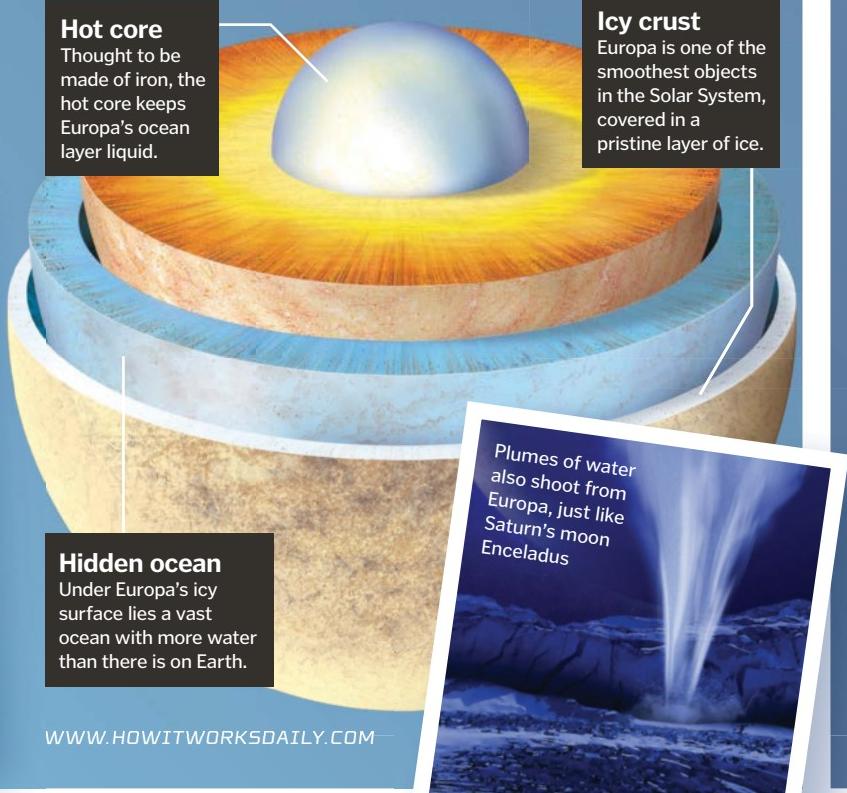
On the surface, things are no less fascinating. Like Enceladus, Europa may also be ejecting plumes of water into space, but it

is the ground itself that is especially interesting. Lines criss-cross beneath your feet, where the icy surface has been pulled apart, revealing warmer layers below. Elsewhere, you'll spot so-called 'chaos' regions, where thick and thin ice on Europa have mashed together to produce iceberg-like features that move across the surface.



**Hot core**  
Thought to be made of iron, the hot core keeps Europa's ocean layer liquid.

**Icy crust**  
Europa is one of the smoothest objects in the Solar System, covered in a pristine layer of ice.



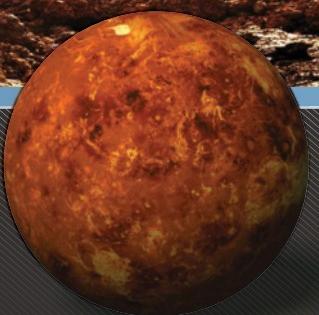
**Hidden ocean**  
Under Europa's icy surface lies a vast ocean with more water than there is on Earth.



Time your trip right and you might spot an active volcano on Venus

# VENUS

## Some like it hot



Journey time: **Three months**  
Nearby destinations:  
**Mercury, The Sun**  
Average temperature:  
**462 degrees Celsius**

It might be the hottest planet in the Solar System, but don't let that deter you from visiting Venus. Between 50 and 60 kilometres above the surface, you'll find the most Earth-like conditions on any other world, as the atmospheric pressure and temperature are the same as on our planet. Here, you can stay on floating colonies as you enjoy the many wonders of Venus, complete with dramatic forks of lightning striking through the atmosphere.

Down on the surface, things get a little toastier. With a scorching hot temperature of several hundred degrees Celsius – hot enough to melt lead – you won't want to venture down unprotected. Explore a little and you'll discover many geological features that are also found back on planet Earth. These include huge canyons, volcanoes, and even ancient lava flows.

**Slow core**  
Venus has a weak magnetic field, which may relate to its slowly spinning core.

**Thin crust**  
A thin upper layer may account for Venus' volcanic activity.



# Taking the Solar System's temperature

## How do we know how hot the other planets really are?

Infrared cameras can reveal hotspots on the human body, and the same techniques can be used to take the temperature of objects in outer space. All objects above absolute zero emit infrared radiation, and the hotter they are, the more they release.

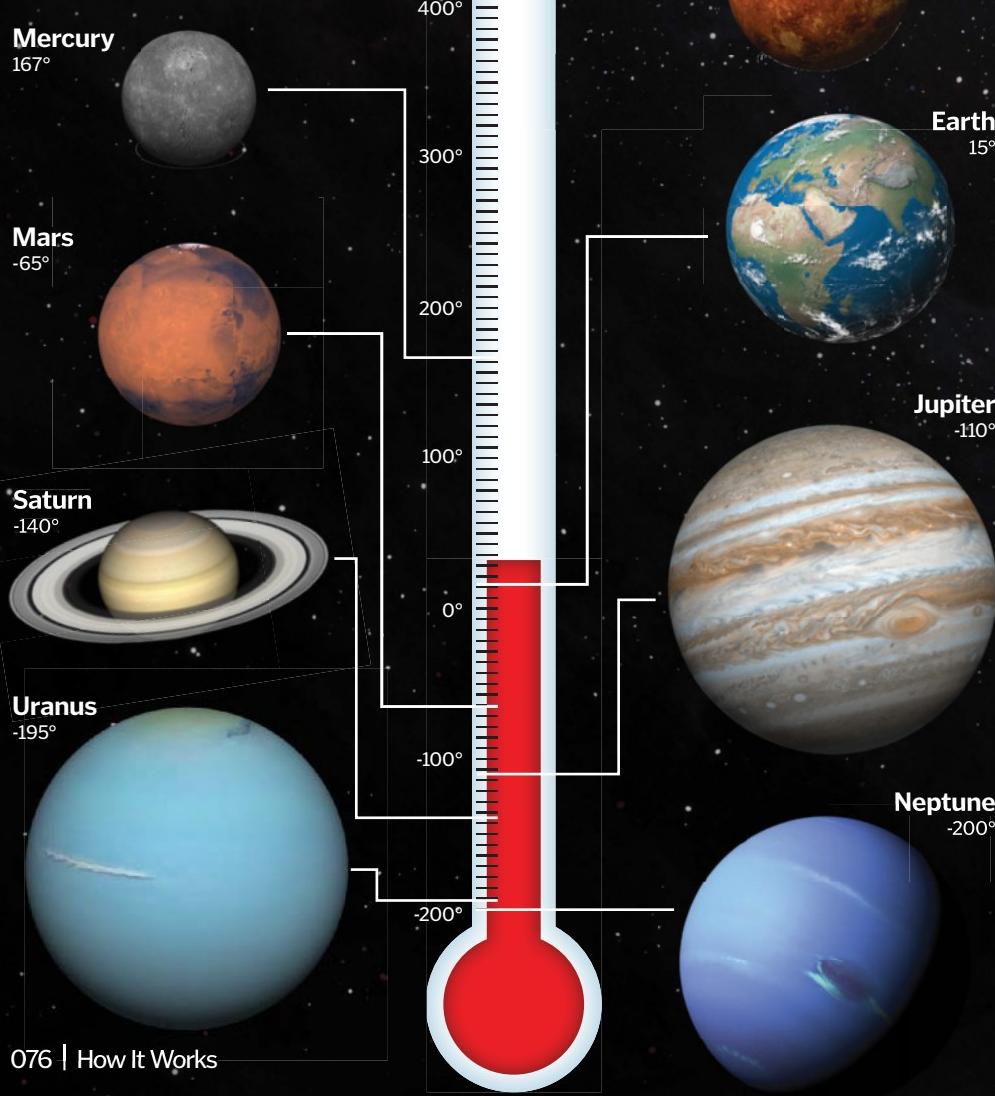
Unfortunately, it is not as simple as pointing a detector at the sky. The gases in our atmosphere absorb infrared light, so to get clear data from planets and stars we need to take our equipment out into space. Sensitive infrared instruments can

be carried by hot air balloons, probes, and space telescopes, like Hubble and Spitzer, allowing us to detect the radiation emitted and reflected by the planets in the Solar System, and by objects even further away.

It is tempting to assume that the closer a planet is to the Sun, the hotter it will be, but this isn't strictly true. The temperature also depends on how much light the planets reflect (known as the albedo), and how good their atmosphere is at holding on to heat (the greenhouse effect).

## Hot or not

The temperature of each planet depends on more than just its distance from the Sun



# Seeing back in time

When we look into space, we are actually looking into the past

If the Sun suddenly vanished, it would take a full eight minutes and 20 seconds for anyone to notice. This is because sunlight does not reach us instantly; it has to travel through space to get here, and that takes time. Light travels at a speed of just under 300,000,000 metres per second in a vacuum, so the delay when looking at nearby objects isn't noticeable, but when we look out into space, we start to experience some serious lag.

The Moon is just over 384,000 kilometres away, so it takes a bit more than a second for its reflected light to reach us. Light from the Sun, at 150 million kilometres away, takes over eight minutes, while light from our next closest star, Proxima Centauri travels for four years. When light travels from our neighbouring galaxy, Andromeda, it takes an incredible 2.5 million years to reach us.

This effectively means that looking out into space is the equivalent to looking back in time, and the further we look, the further back in time we see. Powerful telescopes, like Hubble, are able to see light released by ancient galaxies more than 13 billion years ago.



When this light was emitted by Andromeda, our ancestors hadn't even learnt to use fire

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# Life in the Victorian workhouse

The setting for *Oliver Twist* was a grim reality for society's poor

For the elderly, unemployed and orphaned, life on the cold and filthy streets of Victorian Britain was tough, but better, said many, than the horror of the workhouse. These homes, funded by local taxpayers, were essentially prisons for the poor, where inmates had to follow a strict routine and work their fingers to the bone to earn their keep. Those who didn't would face flogging, imprisonment, or be left on the street for dead. Conditions were kept deliberately meagre to ensure that only the most desperate applied, but one of the most off-putting aspects was the fact that families were separated. Wives, husbands and children were only allowed to see each other for a short 'interview' each day, and in worst cases, only on Sundays.

'Poor relief' has existed in England and Wales since the passing of the Poor Law in 1601, which gave parishes responsibility for looking after the most vulnerable among society.

Workhouses did exist at this time, but as the cost of building them was so high, 'outdoor relief' became the main form of support. This usually consisted of cash payouts, along with food and clothing.

However, the huge influx of injured and unemployed men returning from the Napoleonic Wars in the early 19th century saw the national poor relief bill quadruple. In 1834 the Poor Law Amendment Act was passed, which aimed to end payouts to those able to work. Instead, relief would only be provided in the workhouses, except in special cases. For many penniless Victorians, it was the workhouse or nothing.

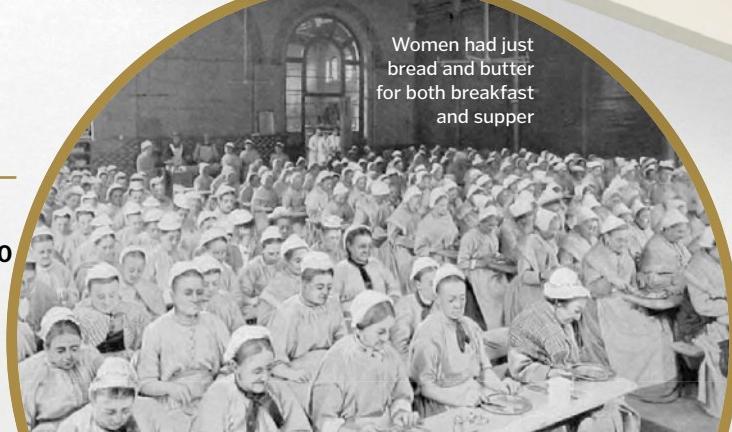
**Dining room**  
Here the inmates were fed basic meals of bread and gruel, with a piece of cheese if they were lucky.

**Laundry**  
Women were set to work doing domestic chores like washing, cooking and cleaning.

**Classroom**  
One of the few benefits of the workhouse was that children were given a free education.

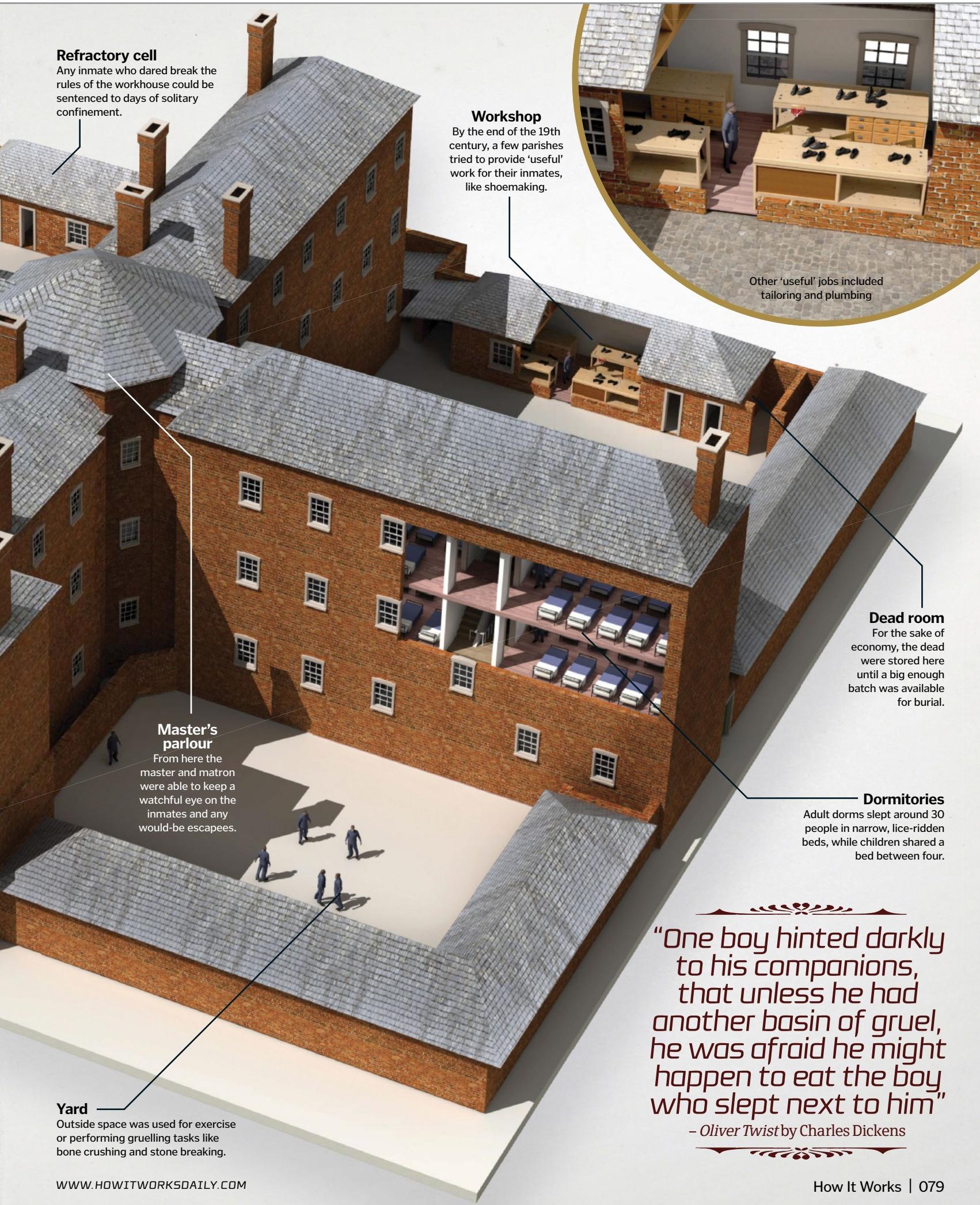
## Inside the workhouse

Sampson Kempthorne's 'cruciform' design made it possible for women, men and children to be kept apart



## Timeline of the daily routine

06:00	Wake up
06:30	Prayers and breakfast
07:00	Work/lessons
12:00	Dinner
13:00	Work/lessons
18:00	Prayers
19:00	Supper
20:00	Bed





Young inmates were taught reading, writing and arithmetic

People ended up in the workhouse for many reasons. Usually, it was because they were too poor, old or ill to support themselves, perhaps because of high levels of unemployment or not having any family to look after them. Unmarried, pregnant women were often disowned by their families, and the workhouse was the only place they could go during and after the birth of their baby. Children who had not been born there often arrived after being orphaned, or if their father was admitted. Once inside, the whole family was split up, with men, women, boys and girls each going to a different section of the workhouse. The only exception was for children under seven, who in some cases were allowed to stay with their mothers in the female section.

Any inmate who was able to work faced day after day of gruelling and monotonous chores.

Women mainly performed domestic jobs like cleaning, cooking and laundry. Some workhouses had workshops for sewing, spinning, weaving and other local trades, while others had vegetable gardens in which to grow produce for the kitchens. Both men and women slaved away picking oakum, which involved teasing out the fibres from old hemp ropes to be sold on to shipbuilders. Tasks given to men included stone-breaking, wood chopping and bone crushing to make fertiliser, although this was banned in 1845 after it was discovered that hungry inmates had resorted to eating the

rotting flesh and marrow on the bones they were crushing. These were backbreaking and hand-blistering jobs, fuelled only by basic food rations of bread and gruel. By the end of the 19th century, a few unions were starting to provide 'useful' work for their inmates such as shoemaking, tailoring, bricklaying or plumbing.

Children seemingly had a better deal, as they were entitled to at least three hours of free school lessons every day – a luxury they would have been unlikely to receive in the outside world. They were taught reading, writing and arithmetic as well as what was described as

"principles of the Christian religion," and other such instructions "as shall fit them for service, and train them to the habits of usefulness, industry and virtue."

However, the reality was that many workhouses were reluctant to spend money on even the most basic

school equipment like writing slates, with many questioning why pauper children even needed to be taught literacy. The living conditions in which workhouse children grew up were appalling, with one visiting physician noting "the pale and unhealthy appearance of a number of children in the workhouse, in a room called the Infant Nursery. These children appear to be from two to three years of age; they are 23 in number; they all sleep in one room, and they seldom or never go out of this room, either for air or for exercise." In another part of the same

**"These were backbreaking and hand-blistering jobs, fuelled only by basic rations of bread and gruel"**



Thomas Barnardo hung a sign outside his children's home saying: "No destitute child ever refused admission"

## On the menu

### BREAKFAST

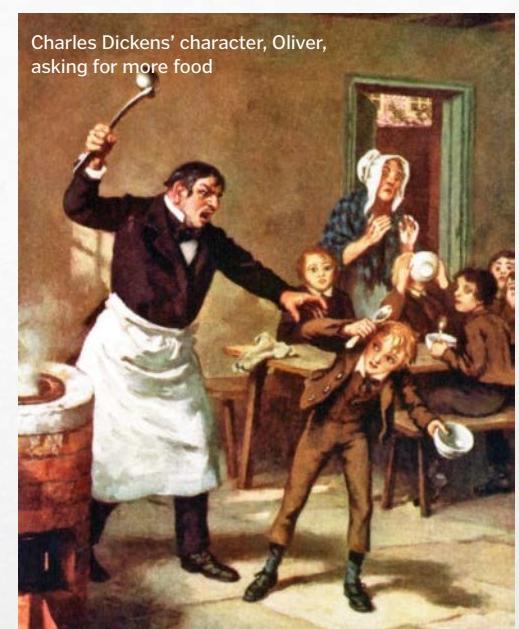
*Bread, butter and tea for women; bread and gruel for men and children*

### DINNER

*Soup, stew or boiled beef with bread and vegetables, with a pint of beer for adults and a half-pint for boys*

### SUPPER

*Bread and butter or cheese, with beer for men and boys, tea for women and milk for girls*



Charles Dickens' character, Oliver, asking for more food

## Diary of a workhouse boy

Master made me go without supper tonight. Not that I care - you can't hardly taste that 'orrible gruel anyway. He said I'd stolen the answers to the spelling test again. I keep tryin' to tell him that it's 'cause Father taught me how to spell before he went off to war, but he won't listen to me. He gave me three lashes of the cane too, and this time it bled real bad. It's still throbbin'. I doubt I'll get much sleep tonight, but at least it'll take me mind off the bed bugs.

I wish Father were still alive. Then we wouldn't have ended up here. And I miss him 'orribly. I miss Ma and little Mary too. Master lets us see each other on Sundays, but it's only for an hour and there are always so many people runnin' round, cryin', shoutin', you can hardly hear yourself think. I miss how Sundays used to be, when Father would buy us each a sticky bun and we'd all eat it down by the river. But those days are long gone now.

Poor Ma, her arthritis is getting much worse. The matron makes her pick ropes apart all day, and her fingers can't take it. And Mary's headin' the same way, what with all that sewin' and mendin' they make her do. The bitter cold don't help much neither. It's all my fault. I'm the man of this family, I should be lookin' after 'em both. One day I'll get outta here and I'll make this family proud again. I swear it.

Children over the age of seven were separated from their mothers



workhouse, 104 girls slept four or more to a bed in a room just 27 x 5 metres in size.

Children were also subjected to abuse, many instances of which were reported by *The Times*, who were firmly against the new Poor Law. One report told of 13-year-old Elizabeth Danes, who after leaving some dirt in the corner of a room, was made to strip off her clothes, lie on a table, and be beaten with a broom until she bled.

One man would attempt to change all that. Thomas Barnardo was an Irish philanthropist who, while training to become a doctor in London, was horrified by the conditions that children there were living in. In 1870, he set up his first home for boys, where they were taught carpentry, metal work and shoemaking. At first Barnardo limited the number of boys allowed at the school, but after an 11-year-old boy who had been turned away was found dead, he decided that he would never do so again. By the time he died in 1905, the charity he founded had opened 96 homes caring for more than 8,500 children.

Despite their gloomy history, workhouses set the stage for a new era of state-funded welfare. When the NHS was founded in 1948, many former workhouses were transformed into hospitals.

## Crime and punishment

Anyone who stepped out of line forfeited 'luxuries' like cheese, or faced solitary confinement

### Neglect of work

No dinner and only bread for supper

### Being noisy and swearing

Locked up for 24 hours with only bread and water

### Fighting in school

No cheese for a week

### Breaking a window

Sent to prison for two months

### Running away

Lashes

### Refusing to work

Sent to prison for 28 days

### Refusing to attend Church

Next meal withheld

### Drinking spirits or smoking

Next meal withheld

### Playing cards or other games of chance

Items confiscated

### Defacing or destroying the list of rules

Fed on bread and water only for two days



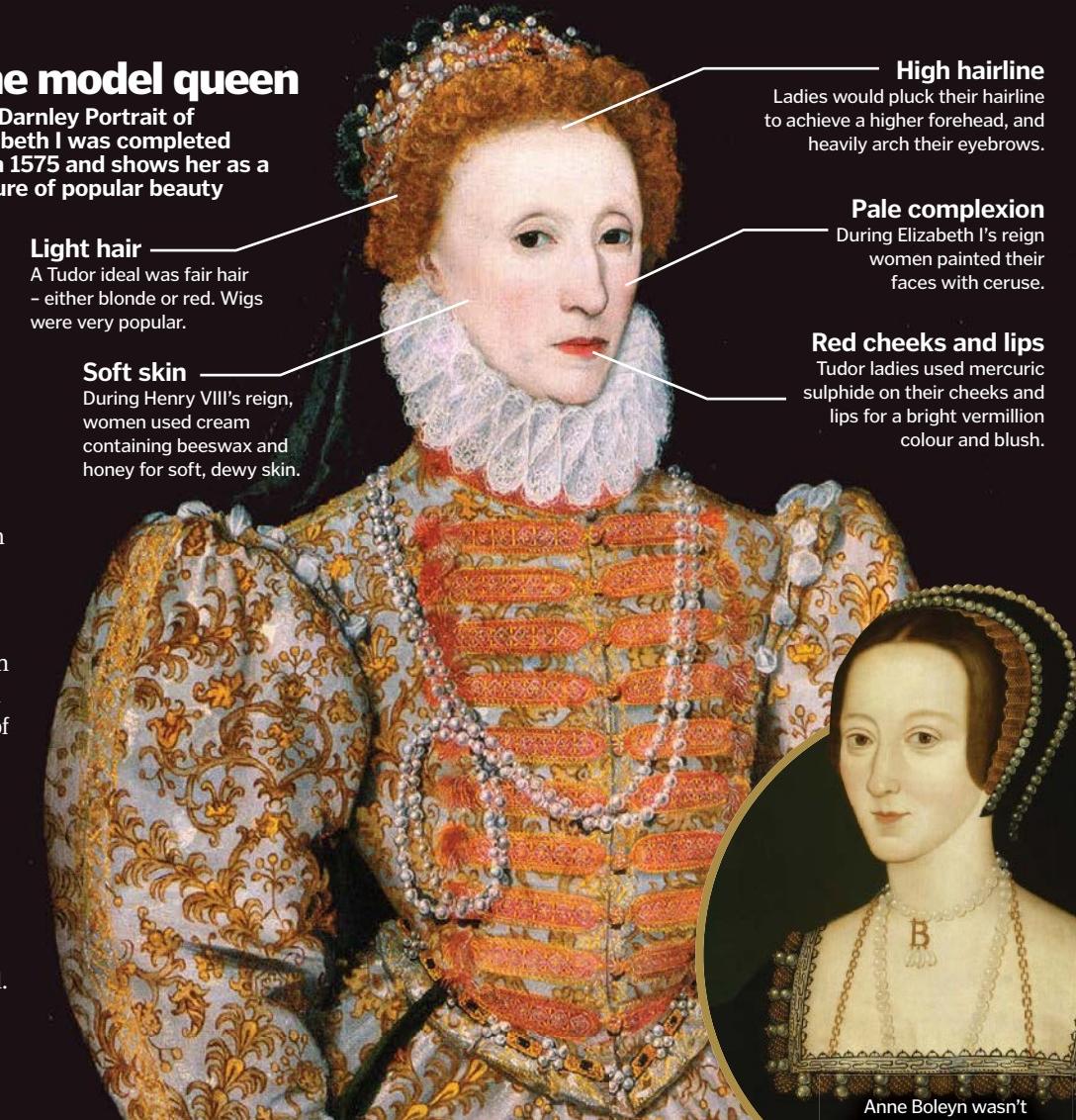
# Tudor beauty

The dos and don'ts of looking gorgeous in 16th century England

**P**erception of beauty varies greatly throughout history, and the Tudors went to great lengths to achieve the ideal. They looked to their Queen, Elizabeth I, for inspiration, so it became very fashionable to have fair hair with porcelain skin and blue or grey eyes.

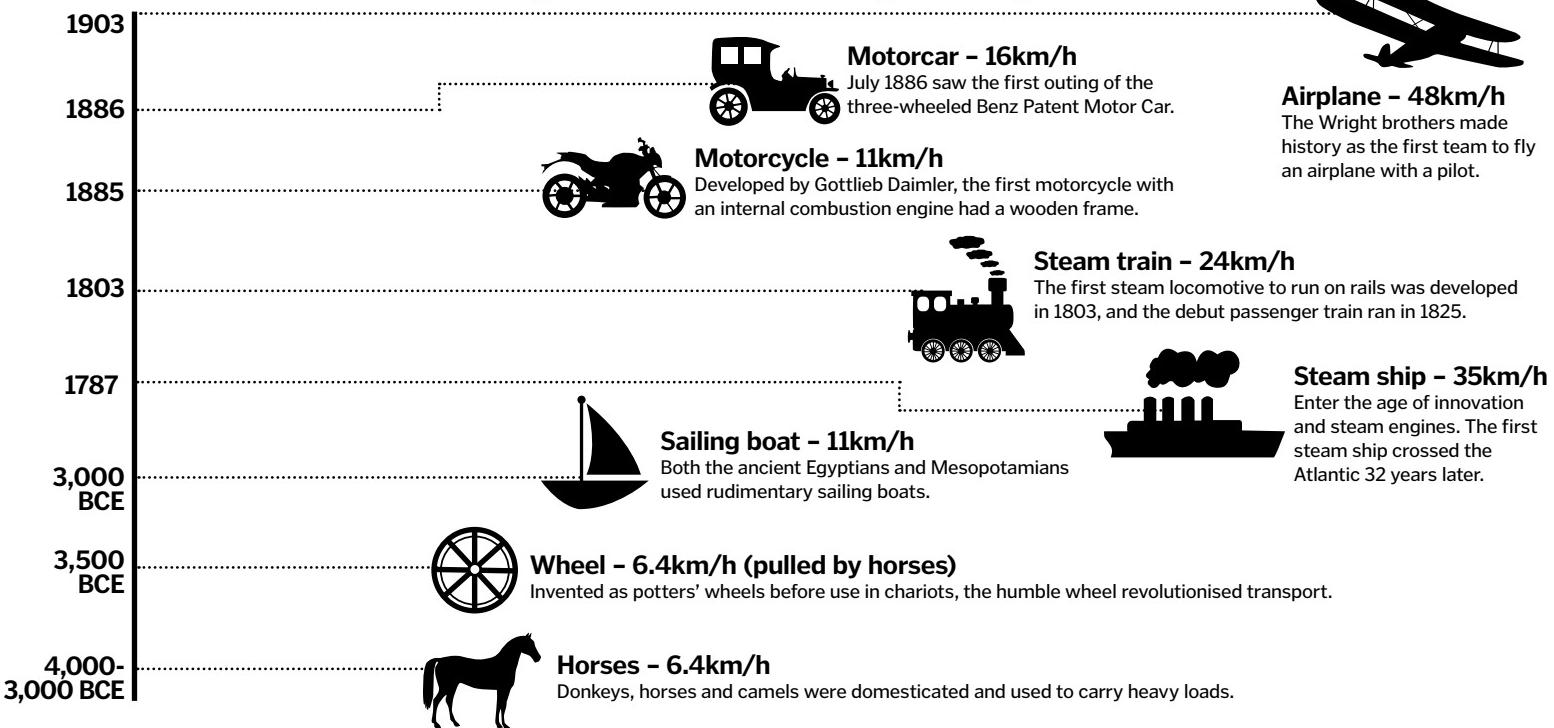
Pale skin was a sign of wealth and relaxation, as by contrast, tanned, freckled or sunburned skin was an indication of hard labour out in the fields. In the early Tudor period, women softened their skin with creams and ointments, but towards the end of the era ladies used ceruse, a cream made of white lead and vinegar, to whiten their complexion. Many suffered from lead poisoning as a result, but they also went to further extremes, such as bleeding themselves to remove any rosy flush.

Darker-haired ladies dyed their locks red with henna, or attempted to lighten it using urine or a mixture of cumin, saffron seeds, celandine and oil. Wigs were also very fashionable, and high-class women would wear these to achieve the desired colour without a messy dye job.



## Travel through time

From cart to motorcar, how we got from A to B through the ages



# Ancient Greek theatre

Uncover the civilisation that invented the play and set the stage for Western culture

We have a lot to thank Ancient Greece for. From democracy to philosophy, this thriving collection of city-states was the birthplace of so many things that we take for granted today – including theatre.

The first mention of it dates back to 532 BCE, when an actor called Thespis performed a tragedy. His name has been immortalised as a term for a performer – a 'thespian'. A few decades later, a festival called the City Dionysia was established in Athens to honour Dionysus, the god of wine. The events centred on competitive performances of tragedies and, from 487 BCE, comedies. Thousands flocked from all over Greece, businesses closed and prisoners were released to take part in five days of festivities.

Performances were staged at the Theatre of Dionysus, considered by many to be the first ever built. This was a huge open-air arena that could seat up to 17,000 people on rows of benches set into a hill. The actors performed in the centre, known as the 'orchestra', while a backdrop was painted onto a building behind the stage known as the 'skene'. This was also where the actors changed into their masks and costumes.

The theatre's acoustics were so well thought out that every single audience member would have been able to hear the actors performing, even in the days before microphones and sound systems. Over two thousand years later, we still base our theatre designs on these incredible ancient structures.



The ruins of the theatre of Dionysus as they appear today

## How to put on a play in Ancient Greece

Follow these steps to produce your very own dramatic masterpiece



### 1 Pick a genre

In Ancient Greece, tragedy and comedy should never mix. The City Dionysia pits the writers of these two genres against each other in its annual theatre competition, so choose a side and get planning.



### 2 Get funding

Plays in Athens are publicly funded, but you will need to pitch your idea to an official, who is known as the eponymous archon, and get his approval, before you see the colour of his money.



### 3 Decide your actors

The eponymous archon is responsible for deciding your lead actors, which is done by drawing random lots. The chorus actors are paid for by wealthy citizens looking to win public favour.



### 4 Start writing

Not only do your plays have to be written in verse, you'll also need to compose the music to accompany them. As for subject matter, the more revolutionary the better.



### 5 Perform your play

Once rehearsals are over, it's time to bring your work to the stage. The competitions can attract up to 17,000 people and last from dawn until dusk.



### 6 Collect your prize

The judges write their scores on tablets and place them in urns. The eponymous archon draws five of them at random and the winner is awarded with a wreath and a goat!

# BRAIN DUMP



Because enquiring minds  
need to know...

## MEET THE EXPERTS

Who's answering your  
questions this month?

### Sarah Banks



Sarah has a degree in English and has been a writer and editor for more than a decade. Fascinated by the world in which we live, she enjoys writing about anything from science and technology to history and nature.

### Laura Mears



Laura studied biomedical science at King's College London and has a master's from Cambridge. She escaped the lab to pursue a career in science communication and also develops educational video games.

### Alexandra Cheung



Having earned degrees from the University of Nottingham and Imperial College London, Alex has worked at many prestigious institutions, including CERN, London's Science Museum and the Institute of Physics.

### Robert Colvile



Robert is the former comment editor and science page editor of *The Daily Telegraph*. His new book, *The Great Acceleration: How the World is Getting Faster, Faster* is about how technology is driving forward the pace of life, and the impact that this is having.

### Shanna Freeman



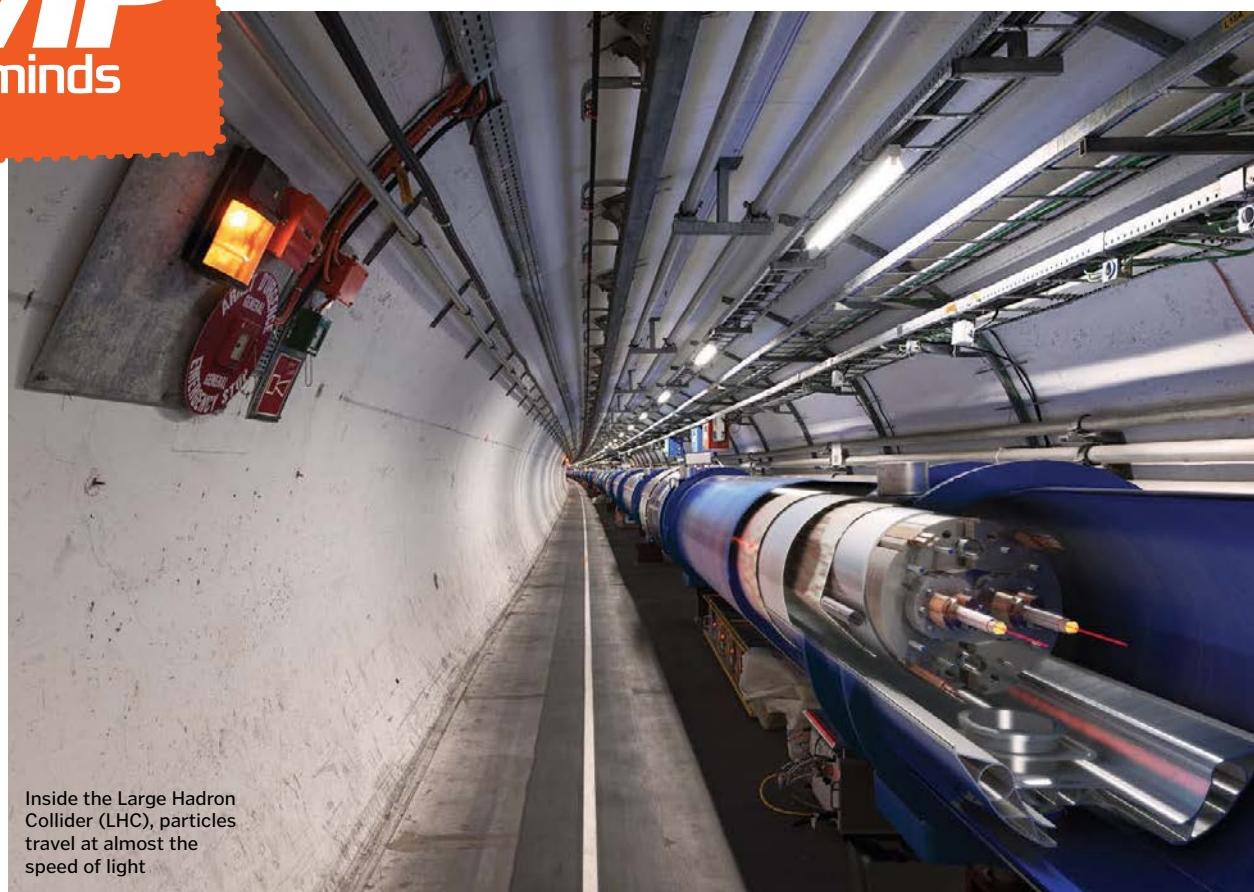
Shanna describes herself as somebody who knows a little bit about a lot of different things. That's what comes of writing about everything from space travel to how cheese is made. She finds her job comes in very handy for quizzes!

## Want answers?

Send your questions to...

How It Works magazine @HowItWorksmag

[howitworks@imagine-publishing.co.uk](mailto:howitworks@imagine-publishing.co.uk)



Inside the Large Hadron Collider (LHC), particles travel at almost the speed of light

## Is it possible for a solid to move at light speed?

### Jacob Samson

Einstein's theory of relativity states that it's impossible for an object with mass to travel at the speed of light. Accelerating an object requires energy, and as the speed increases, the amount of energy required to speed it up any further increases. Getting it to the speed of light would require an infinite amount of energy,

which is impossible. This is due to the relationship between mass and energy. The faster an object moves (i.e. the more energy it has), the greater its mass.

Despite this, some things can travel at 99 per cent or more of the speed of light. Inside man-made particle accelerators, particles typically travel at speeds just a few metres per second shy of the speed of light. AC



Some of the hottest places on Earth are in subtropical regions, including Death Valley in the US and the Lut desert in Iran

## Why are the tropics hotter than the equator?

### Yanar Mistry

The equator is the latitude that falls at the point on Earth that is an equal distance from the North Pole and the South Pole, making it zero degrees latitude. The tropics surround the equator; the Tropic of Cancer is north of the equator, whereas the Tropic of Capricorn lies to the south. Sunlight hitting the equator generates rising air currents, contributing to cloud cover and thunderstorms which reduce the air temperature by several degrees. At the subtropics, around 20° to 40° above and below the equator, the atmosphere is more stable, so there is little cloud cover. This creates hotter and drier climates than those experienced at the equator. SB



Contaminants react with chlorine in pool water, creating chemicals that can irritate the eyes

## What does chlorine do to our eyes?

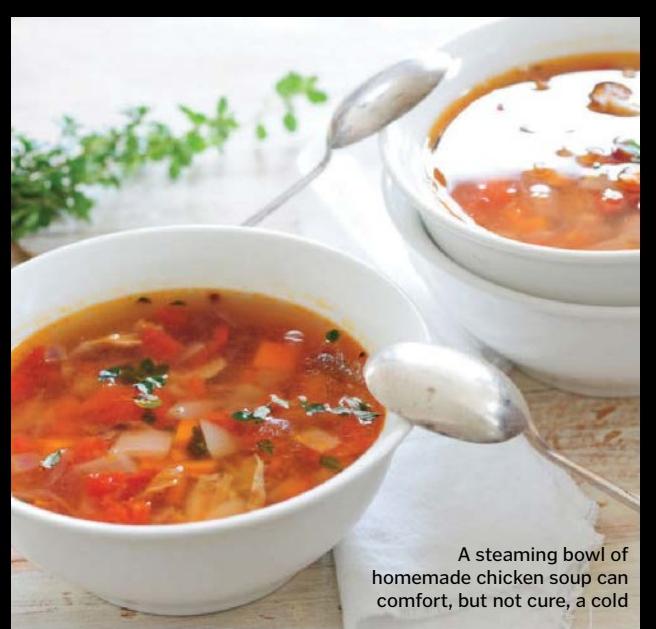
**Mathieu Tabrah**

■ Chlorine is used as a disinfectant in pools (between 0.5 and 1.5 milligrams per litre), and in tap water (less than 0.5 milligrams per litre). In tests on healthy volunteers, researchers at Ryogoku Eye Clinic in Japan found that 0.5 milligrams per litre was enough to cause some damage to the cells found in the thin, transparent layer covering the front of the eye. However, getting red, itchy eyes after swimming cannot solely be blamed on chlorine; when the chemical mixes with urine, sweat, oils and cosmetics, it can produce substances that are much more irritating. **LM**

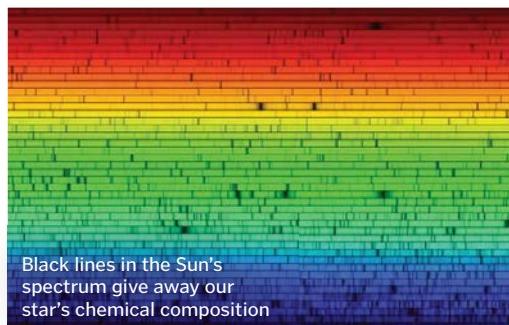
## Does chicken soup actually help a cold?

**Kane Brackley**

■ Mothers have long prescribed chicken soup for a cold. While eating it can't cure you, there's some science to show that chicken soup is probably still helpful when you're ill. The hot liquid eases congestion and keeps you hydrated, but the soup itself also contains nutrients with anti-inflammatory properties. In one study, chicken soup kept a type of white blood cell called neutrophils from migrating, which may help reduce cold symptoms. Other nutrients, like Vitamins C, D and E, can also influence immune cells and chemicals. Scientists aren't yet sure why it works, but it certainly seems to be more than the placebo effect. **SF**



A steaming bowl of homemade chicken soup can comfort, but not cure, a cold



Black lines in the Sun's spectrum give away our star's chemical composition

## How do we know what stars are made of?

**Lois Cattermole**

■ Astrophysicists learn what stars are made of by studying the light they emit. Light reaching Earth from a star can be analysed using a spectrometer, which separates it out into a spectrum of its constituent colours. However, the spectrum is not a continuous sequence – certain colours of light are absent. This is because elements within the star absorb specific wavelengths. Sodium, for example, absorbs yellow light strongly. By seeing which wavelengths are missing, scientists can deduce which elements make up the star. **AC**

## What makes a gemstone precious or semi-precious?

**Siobhan Montague**

Mostly marketing! According to the German expert Max Bauer, precious stones are "the minerals which combine the highest degrees of beauty, hardness, durability and rarity". These include diamond, ruby, sapphire and emerald. However, it is hard to distinguish between

precious and semi-precious stones. Amethyst is only classified as semi-precious because it is more common than opal or turquoise, even though it is harder. In practice most 'precious' stones have received this label down to economics and aesthetics, rather than any mineral or chemical properties. **RC**



Diamonds are considered precious because of their rarity rather than their structure

## FASCINATING FACTS

### Did footballs really used to be made of pigskin?

American footballs are thought to have begun as inflated pig bladders, later encased in cowhide leather said to be as tough as the skin of a pig. Today the 'bladders' are synthetic and surrounded by leather or rubber. **SF**



No pigs were harmed in the making of this American football



Pterodactyls are properly known as pterosaurs, and aren't dinosaurs at all



## Why aren't pterodactyls classed as dinosaurs?

Lara Greenfield

It seems that we have oversimplified the naming conventions for prehistoric creatures. 'Pterodactyl' is the informal name for winged reptiles, properly known as pterosaurs. These flying creatures lived among dinosaurs from the Triassic to the Cretaceous

period but weren't classified as dinosaurs. The two groups have a shared common ancestor, but diverged to evolve unique characteristics. Modern birds are likely to be descended from small, feathered, land-based dinosaurs, not pterosaurs – or pterodactyls, for that matter. SF

Helium balloons can reach about 48km up before they burst



## How high can a helium balloon float?

Jerome Thornton

A balloon is pushed upwards by the difference in pressure between the gas inside and the atmosphere. In theory, it should rise to the point where the atmospheric pressure matches that of the helium – so up to the mesosphere (which starts around 48 kilometres up) but

probably not beyond. The problem is that in practice, the same pressure differential that causes balloons to rise also causes them to expand, and then to burst. Using the lightest, stretchiest material they could find, a Japanese team reached a height of 53 kilometres in 2002, hitting the bottom of the mesosphere. RC

## FASCINATING FACTS

### When was the first mirror invented?

Basic mirrors first appeared in prehistoric times, in the form of polished rocks (such as obsidian) and later metal. It wasn't until the 1500s that glass-making advanced enough to make mirrors as we know them. The Venetians 'silvered' these with tin and mercury. RC



Mirrors like the ones we use today were invented in the 1500s

### What's the highest anyone can count?

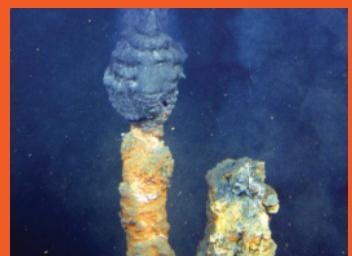
There's really no upper limit, but people don't live long enough to count very high at all. If you counted one number every second for your entire life, you'd only get up to around 2,522,880,000. LM



The world record for counting aloud is held by Jeremy Harper, who got to one million in 89 days

### What's the hottest temperature life can survive at?

Methanopyrus kandleri, a microbe that lives in deep sea vents, is able to endure temperatures of up to 122°C, hotter than any other organism. AC



Deep sea vents are one of the most extreme places where life is found



Phantom vibrations may not all be in the mind

## Why do you think your phone is vibrating when it's not?

**Victoria Gilly**

Good question! The honest answer is that scientists aren't quite sure. The consensus, however, is that it's not just in the mind; what's probably happening is that our brains are misinterpreting real physical signals, whether that is a gust of air, a muscular twitch, or even electrical signals from the phone itself jangling our nerves. It's striking that the people who report more phantom vibrations are those who are novelty-seekers – they are so alert for new information via their phones that they're happy to put up with a few neurological false alarms. **RC**

## Do we really eat spiders in our sleep?

**Sam Jaffe**

It is very unlikely that we will eat even one spider in our lifetime, never mind the half a dozen per year we're led to believe. Although possible, swallowing a spider would require several things to happen at once. We would need to have our mouth open as we slept; there would have to be a spider in the bed, which is rare in itself, particularly when that bed contains a wriggling, breathing human; the spider would need to be brave enough to enter the warm, wet and dark orifice that is our mouth; and finally we would have to physically swallow it. So although not impossible, it is highly unlikely! **SB**

It's very unlikely that we will ever eat a single spider in our sleep



## Why is the Moon slowly moving away from us?

**Colin Gray**

The action of ocean tides is causing the Moon to gradually drift away from Earth. The Moon's gravitational pull on our planet's water creates a slight bulge on the ocean surface on the side of the Earth that is closest. This bulge in turn exerts a gravitational pull on the Moon. But as the Earth rotates, the bulge moves forward in relation to the Moon. As a result, the Earth's rotation slows slightly, giving a little bit of energy to the Moon, making it orbit slightly further away. Each year, the Moon edges about 3.78 centimetres further away. **AC**

The Moon's drift is related to ocean tides



Penguins do get cold feet, but are still able to use them



## Do penguins get cold feet?

**Frankie Tippett**

Although penguins do get cold feet, they are still able to function due to the way their feet are operated. The tendons that are attached to their ankle and toe bones pass through muscles in warmer parts of their bodies. Though their feet may become cold, the muscles that operate them are still at a normal body temperature. When the external temperature drops significantly, feathers and the fat layer of the body protect the feet, which are not allowed to go below freezing. Blood flow also adjusts to ensure this. **SB**

## What makes green tea good for you?

**Tish Higgins**

Green tea is sometimes labelled as a 'superfood', but this is nothing more than a marketing term. The claims that this popular beverage can prevent cancer, aid weight loss or slow Alzheimer's disease have not been proven, but green tea does contain vitamins and minerals that are an important part of a healthy diet; it provides B vitamins, manganese, potassium, magnesium and antioxidants called catechins. According to the British Dietetic Association, the evidence that green tea is a miracle food is poor, but it is safe to drink in moderation. **LM**

Many of the health claims surrounding green tea have not been confirmed





## Does singing to plants help them grow?

Clover Fulton

Not much research has been done on the relationship between music and plant growth, although the theory has been around since the 1850s. Some researchers believe that sound – if you think of it merely as vibrations – is a form of environmental stimulus that can affect the plant. For instance, perhaps it tends to grow harder in windy conditions, and the vibrations imitate this. In the most recent experiments, plants that were played music or spoken to did grow better than the control plants left in silence. However, it's probably more important to provide a plant with light, water and soil than this week's Top 40. SF



Playing music for your garden may yield a better crop, but other factors will have more effect

## FASCINATING FACTS

### What is the tiny pocket in a pair of jeans for?

This small pocket dates back to the 1800s when cowboys would wear their watches on chains. Levi's introduced a small pocket on its jeans where the cowboys could keep their watches. SF



This tiny pocket is just the right size for a cowboy's watch

### Why do oysters make pearls?

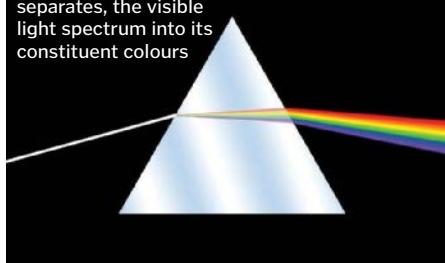
Eve Atri

An oyster is a mollusc, and therefore has a hard outer wall known as a mantle, which covers and protects certain organs. When an intruder – such as a grain of sand – enters an oyster's shell and lodges itself between the shell and the mantle, it irritates the oyster, causing it to promptly cover the foreign body with a mineral substance that it secretes from its shell, called nacre – also known as mother of pearl. The oyster coats it with more and more nacre until it forms a pearl. The shiny spheres are actually therefore the product of an immune response. Pearl 'farmers' can trigger the response by inserting a grain of sand into the shell. SF



Pearls are created as a reaction to an intruder entering the oyster shell

A prism refracts, or separates, the visible light spectrum into its constituent colours



### What is the wavelength of black and white light?

Rosie Chacksfield

In terms of the electromagnetic spectrum, black isn't a colour; it's the absence of visible light. The term 'black light' usually refers to a type of lamp that operates in or near the ultraviolet (UV) range. The lamps have a violet filter that blocks out visible light and lets the UV light through. We can't see this type of light, which is why we call it black. White isn't a colour either, at least not in the sense that we see one wavelength as 'white'. Instead, it's the combination of all of the colours in the visible light spectrum. The wavelengths are between 400 and 700 nanometres, ranging from red to violet. Red light has the longest waves and violet has the shortest. SF



Our ancestors did not need to hibernate to survive the winter

## Why can't humans hibernate?

Priya Kernek

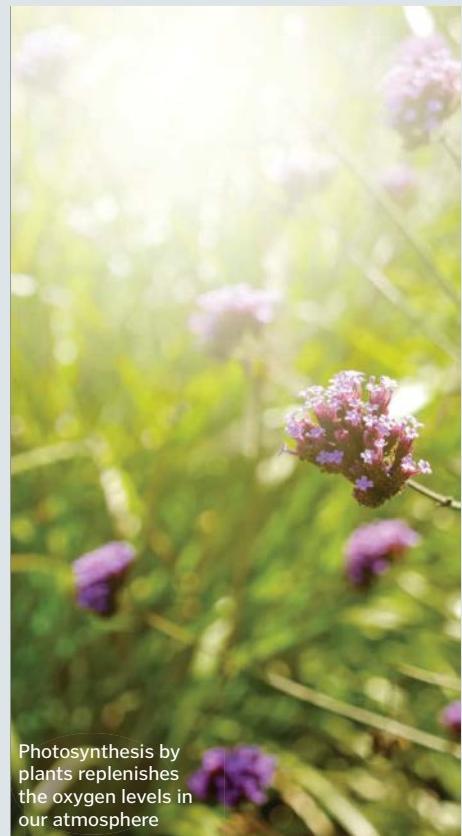
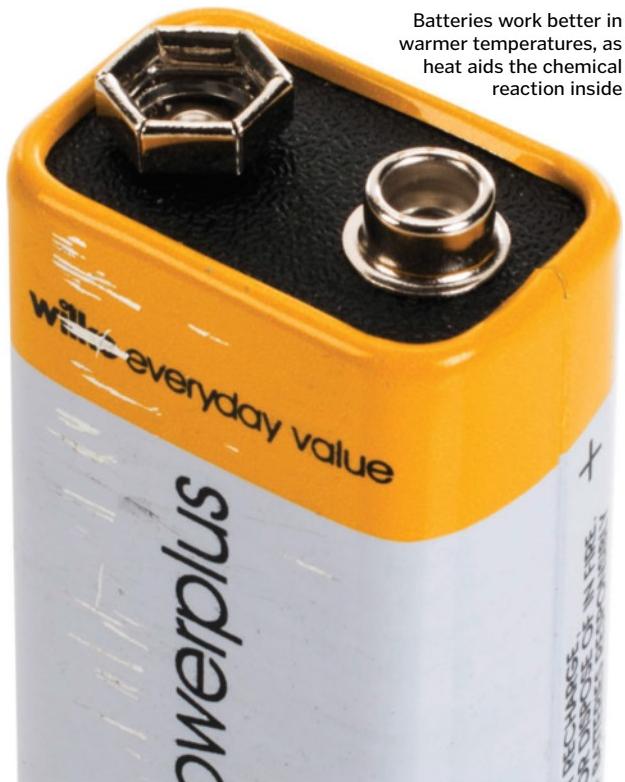
The simple answer is because we don't need to. Animals hibernate to cope with the lack of food as the seasons change, and to avoid predators, but early humans originated in East Africa, where the weather is generally warm year-round. We are large and intelligent, able to avoid predators and stockpile food, and we make clothes, houses, blankets and fires to keep ourselves warm.

Even if we wanted to, we couldn't hibernate. Animals that can hibernate slow their bodies right down, dropping their temperature, breathing and heart rate, decreasing the energy demands of their cells, and surviving on stored fat through the winter. Our hearts cannot cope with temperatures below 28 degrees Celsius, and although some people can slow their metabolic rate, the ability is rare and has potentially serious side effects. LM

## How does temperature affect battery power?

Mona Hirai

Computers work better when they're cooler, so you'd expect the same to be true for batteries, right? Wrong. The current inside a traditional battery is produced by a chemical reaction that generates electrons. The warmer it is, the more vigorous that reaction – and vice versa when it's cold. That's why car batteries tend to fail in winter, and why you might be able to coax them back into life by heating them up. However, there's a sting in the tail here. Batteries certainly generate more power when they're warm, but they also have a shorter lifespan – partly because of the extra power they're putting out, and partly because of the risk of damage to individual cells from overheating. The rule of thumb for lead-acid batteries (the kind used in most cars) is that increasing the temperature by eight degrees Celsius cuts the battery's life in half. RC



Photosynthesis by plants replenishes the oxygen levels in our atmosphere

## Could the Earth ever run out of oxygen?

Amanda Ambrose

Oxygen is continually being produced by plants and a variety of chemical processes, so it is very unlikely that we would ever run out of it. Plants (including tiny phytoplankton in the ocean) use the energy from sunlight to convert carbon dioxide and water into sugars and oxygen, a process called photosynthesis. This replenishes the oxygen used up by respiration or chemical reactions such as combustion. Even if plants stopped photosynthesising, we have enough stores of oxygen in our atmosphere to support human and animal life for at least a few hundred years. AC

© Thinkstock/Dreamstime/NASA

## How do antiseptics work?

Jason Roome

Antiseptics prevent infection by stopping the growth of bacteria, fungi and other microorganisms. Unlike antibiotics, antivirals and antifungals, these chemicals are only used outside the body, on the skin. Disinfectants are similar, but are used mainly on hard surfaces like counter tops.

Most antiseptics work by getting inside microorganisms and disrupting their function, but different chemicals have different effects. For example, some cause cells to leak or burst open, others interfere with the production of essential molecules, and some prevent microbial cells respire, grinding their biology to a halt. SF



Alcohols interfere with the shape of essential molecules and dissolve bacterial membranes

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# BOOK REVIEWS

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## The World Water Speed Record: The Fast And The Forgotten

Spectacle meets tragedy in the quest to take on the elements

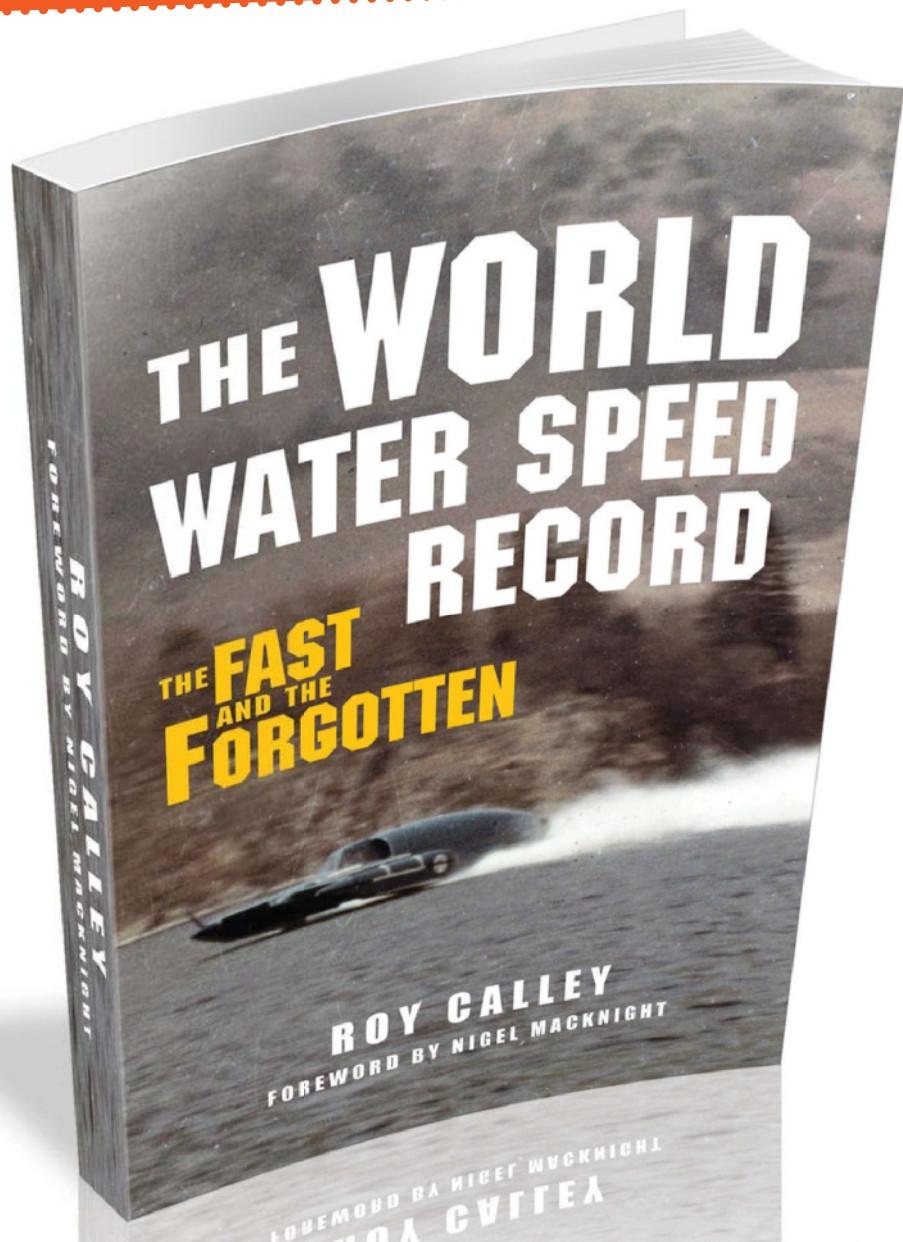
- Author: Roy Calley
- Publisher: Amberley
- Price: £8.99 / \$14.50
- Release date: Out now

The chasing of assorted world records has been a recurring trait of human character for centuries. One of the most intriguing of these goals has been that of the water-speed record, a dangerous target that nonetheless produced a variety of attempts at reaching it, the most notable of which are detailed in this book.

Author Roy Calley, who has a long history of working in sports journalism, displays a lot of affection for the source material. Most of the time this is a good thing, manifesting itself in tirelessly researched mini-biographies about the lives of such indomitable figures as Henry Segrave and Malcolm and Donald Campbell. Inevitably, the book is focused more on their achievements than anything else. Nuanced it isn't, but then in a book concerned with 'speed freaks' – as its subjects are regularly called throughout the book – this clearly isn't the aim.

But then in the second half, everything changes. We follow Donald Campbell in his final record attempt, when the world was no longer as entranced by his escapades as they once had been. Thus we bear witness to his final and ultimately fatal attempt on 4 January 1967 in Coniston Water, reading his final words spoken in pursuit of greatness. With his private life an unhappy one at the time, it seems fitting – if undeniably bittersweet – that ultimately he went out doing what he loved, and Calley leaves this in no doubt whatsoever.

With subsequent attempts coming from America and Australia, you get the sense that Campbell's death marked the end of an era of



sorts. Perhaps Britain was moving on, allowing the book to conclude with a degree of self-reflection; why exactly did these people attempt a record? It wasn't for fortune – most were already rich, and the most famous of them were the ones who died in the attempts.

Intentionally or otherwise, in examining this particular speed-based holy grail, a book has been crafted not so much about the world record itself, but more about the fascinating characters involved.



### YOU MAY ALSO LIKE...

#### The Reluctant Rocketman

Author: Sarah Kasprowicz  
Publisher: GreenBean Creative Solutions  
Price: £9.99 / \$14.95  
Release date: Out now

The story of the man who broke the land-speed record in 1970, as penned by his daughter. A heartfelt and hilarious read, speed buffs will get a lot out of this.

#### Bluebird And The Dead Lake

Author: John Pearson  
Publisher: Aurum Press  
Price: £10 / \$15.95  
Release date: Out now

A biographical account of Donald Campbell in happier times, when he broke the land-speed record with the iconic Bluebird, despite events doing their best to transpire against him.

#### Life With The Speed King

Author: Leo Villa  
Publisher: Marshall, Harris & Baldwin Ltd  
Price: Approx £14 / \$20  
Release date: Out now

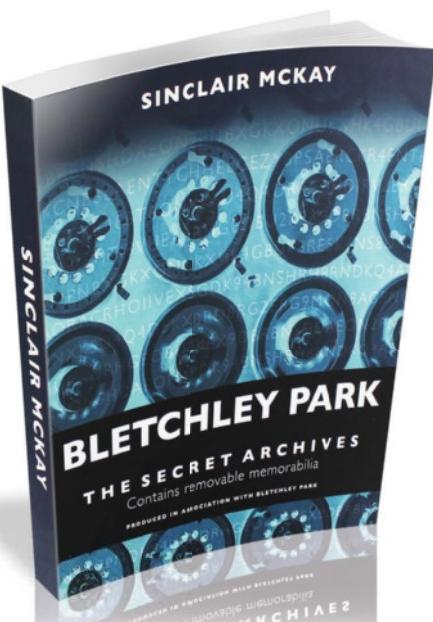
The former mechanic of both Malcolm and Donald Campbell chronicles his life working with the pair in a series of recollections and photography from their heyday.

## Bletchley Park: The Secret Archives

WWII's secrets continue to unravel

- Author: Sinclair McKay
- Publisher: Aurum Press
- Price: £30 / \$40
- Release date: Out now

To this day, the activities of the conspicuously mundane works at Bletchley Park continue to intrigue, as the extent to which they aided the war effort has been revealed. Galvanised by public interest in characters like Alan Turing, this collection provides a fascinating insight into their work, as well as a selection of removable memorabilia.



There are handwritten memos from important figures like Turing himself, and even a letter from Winston Churchill giving code breakers extra resources. Thumbing through this slipcased collector's edition will make you feel as though you are holding history in your hands.

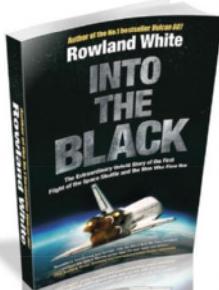


## Into The Black

Heading towards the final frontier

- Author: Rowland White
- Publisher: Bantam Press
- Price: £18.99 / \$29.99
- Release date: Out now

Published to commemorate the 35th anniversary of the maiden flight of the Space Shuttle Columbia, *Into The Black* tells the gripping story of both those who boarded the revolutionary new Space Shuttle as it traversed unknown waters, and of those who were responsible for keeping them safe as they reached space for the first time in history.



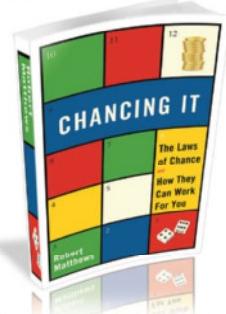
It's a story that has been told relatively little in comparison to various space misadventures like Apollo 13 and Columbia's own disastrous final flight in 2003, so it's refreshing to see it told with such vivacity and aplomb. Using interviews, recently declassified information and a superb talent for storytelling, White both provides an education and puts the reader in the shoes of those involved along the way. This is the definitive word on Columbia.



## Chancing It: The Laws Of Chance And How They Can Work For You

May the odds be ever in your favour

- Author:  
**Robert Matthews**
- Publisher:  
**Profile Books**
- Price: £14.99 / \$15.55  
(e-book only in US)
- Release date:  
**Out now**



Everyone knows about probability and the effect that luck and chance can have on our daily lives, but few know how to apply these laws in such a way that they work in our favour. Author Robert Matthews claims to have the answer.

Looking at activities like gambling and playing the stock markets, as well as analysing the ways in which medical diagnoses aren't always as obvious as they seem, this is a book that has the utmost confidence in what it's saying. Matthews' statistical theories could make your life a whole lot 'luckier'.

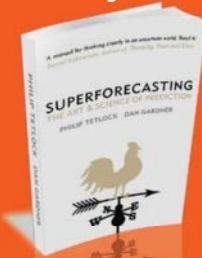


## Superforecasting: The Art & Science Of Prediction

Foreseeing the future made easy

- Author: Philip Tetlock, Dan Gardner
- Publisher: Random House
- Price: £14.99 / \$28
- Release date: Out now

Described in its own press release as "an exciting story of ordinary people beating experts in a very serious game" and "a manual on how to think clearly about an uncertain world", the appeal of *Superforecasting* relies on you taking it at face value. If this is something you can engage with, then you could be in for an interesting read. From its series of exercises aimed at improving an average person's ability to predict future events, through to case studies of other so-called 'superforecasters', this is a book like few others. If not a game-changer, it is undoubtedly intriguing.



## The Mysterious World Of The Human Genome

Mapping the human body

- Author: Frank Ryan
- Publisher: William Collins (UK), Prometheus Books (US)
- Price: £20 / \$28
- Release date: Out now

Noted physician and evolutionary biologist Frank Ryan breaks down the complexities of the human genome so that you can understand the biochemistry that defines who you are. It's a mind-boggling topic, with as many twists and turns as a strand of DNA, but Ryan manages to make it accessible and enlightening. He guides us through the last 50 years of scientific discoveries, explaining how the genome has helped us to find cures for genetic diseases, trace our ancestors and more.

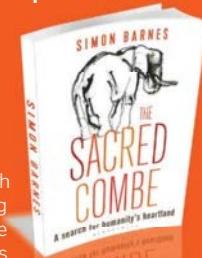


## The Sacred Combe: A Search For Humanity's Heartland

Going back to that special place

- Author: Simon Barnes
- Publisher: Bloomsbury
- Price: £14.99 / \$25
- Release date: Out now

The Sacred Combe is not an exotic hair accessory. Rather, it refers to the place in which the author feels safe and at one with the environment. Simon Barnes is referring to the Luangwa Valley in Zambia, where he woke on his first morning to find elephants eating the roof of his hut. In this book, he chronicles his exploration of the area and other nearby locations with short chapters, making it easy to pick up and put down. It's such a personal account, full of description and memories, that it won't appeal to everyone, but it's clear that Barnes has poured his heart and soul into it.



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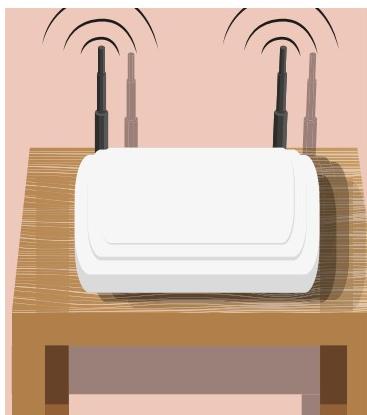
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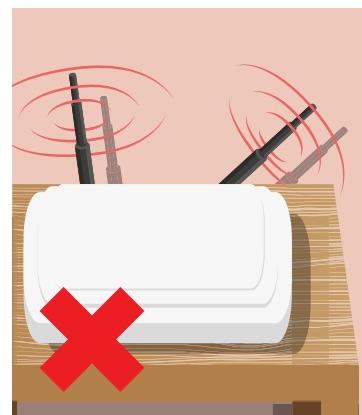
# Improve your home Wi-Fi signal

The science behind getting a better signal and faster broadband



### 1 Raise it up

Your Wi-Fi router might not be the most attractive thing in your home, but that doesn't mean you should hide it on the floor behind your TV. Wi-Fi signals travel down and sideways more easily than they travel up, so raise your router by putting it on a table or cabinet to give better signal throughout your house. It doesn't have to be much, but the higher it is, the better your connection will be.



### 2 The right angle

If your router has an antenna that can be moved and repositioned, it can be tempting to point it towards the devices you use the most. However, this is a bad choice – the signal is actually emitted from the sides of the antenna, so angling it at all will simply result in most of the signal being shot straight into the floor or ceiling. It is best to just keep the antenna pointing vertically.



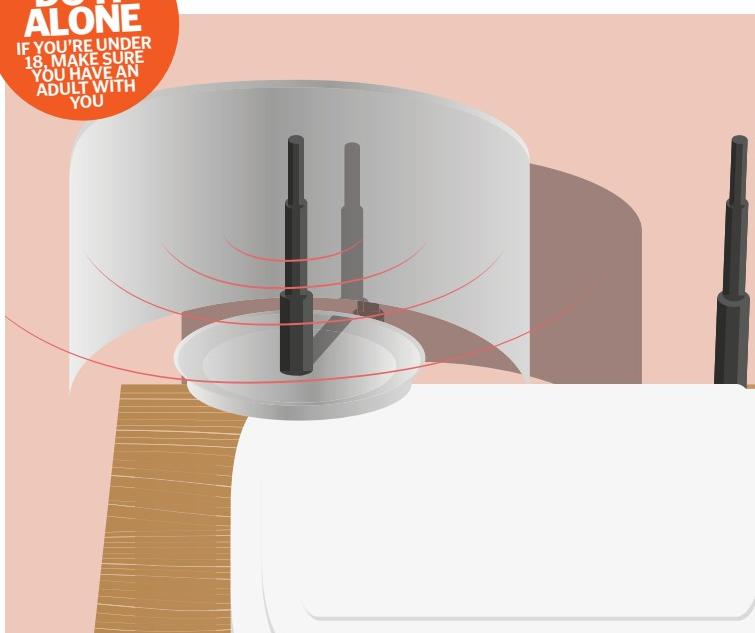
### 3 Centralise the signal

In many homes, the position of the Wi-Fi router is entirely dependant on where your ports are, but if possible, try to position your router so that it is in the very centre of your house. This will ensure the signal is beamed evenly throughout your home – if you keep your router right up against one wall on the ground floor, upstairs rooms on the other side of the house will suffer.



### 4 Remove interference

We're not talking about knocking down walls here – although thick walls (especially those lined with any form of metal) can be a big disruption to Wi-Fi signals. Instead, try to keep your router away from other electronics and metal objects, and as far as possible from any routers that your neighbours may be using. These things can cause interference that blocks your signal.



### 5 DIY booster

If you really have to put your router right by a wall on the far side of your house, you could try a DIY solution to improve your signal. Carefully cut a large drink can so that the thin metal forms a curved sheet. Then, cut the bottom out of a pie tin and make a hole in the centre. Place the pie tin base over the antenna and position the curved metal to form a kind of satellite dish – this will reflect the signal back into your home.

### In summary...

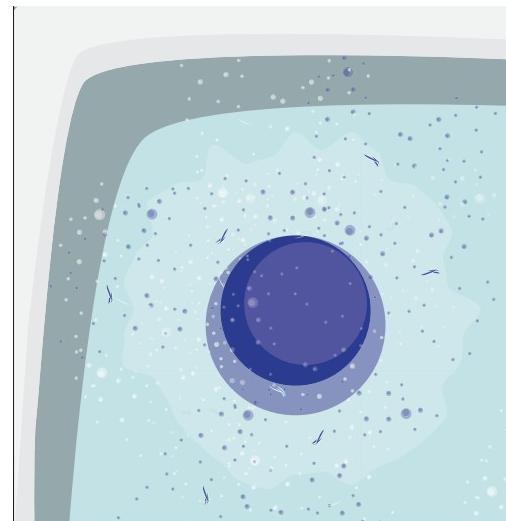
Your WiFi router converts Internet data into radio waves, which it then transmits to your computers and other devices. These waves travel in straight lines and can be weakened if other objects or signals lie in their path – just like when your car radio goes fuzzy when you enter a tunnel.



**Disclaimer:** Neither Imagine Publishing nor its employees can accept liability for any adverse effects experienced after carrying out these projects. Always take care when handling potentially hazardous equipment or when working with electronics and follow the manufacturer's instructions.

# Make a bath bomb

Enjoy a bathtime treat with a little chemistry thrown in!



Illustrations by Edward Crooks

## 1 Add the ingredients

Grease a muffin tray or mould with almond oil, then in a bowl, mix together three tablespoons of citric acid and ten tablespoons of bicarbonate of soda. In a separate bowl, mix 12 drops of essential oil, ten teaspoons of sweet almond oil and 15-20 drops of food colouring. The almond oil will help moisturise your skin in the bath, and the essential oil will smell nice when you're relaxing. Make sure you choose an oil suitable for bath bombs, not just candles!

## 2 Mix it up

Bit by bit, pour the oil mixture into the dry mixture, stirring well each time you add more. If the mixture starts to foam up, it's because you're adding the oil too quickly, so slow down and take your time! The mixture is ready when it has a thick consistency, similar to that of damp sand. Spoon the mixture into your muffin tray and press down firmly to form solid blocks. Depending on the size of your tray you should get three or four bath bombs from this mix.

## 3 Set and enjoy!

You'll need to set the bath bombs aside for a few days to allow the mixture to set properly. Once they're hard, all you need to do is carefully remove one from the muffin tin and drop it in your bath! When the bath bomb hits the water, this sets off a chemical reaction between the citric acid and the bicarbonate of soda. During this reaction, carbon dioxide is formed, and these bubbles are what cause the fizzing you see in the bath.

### In summary...

The bicarbonate of soda and citric acid won't react together when they're in powder form, but when they are dissolved in water, the two chemicals react to produce carbon dioxide, which is released as tiny bubbles. These fizz around the surface of your bath, and help to release the sweet smells of the essential oils.



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Who was the first person to reach the South Pole?

- a) Roald Amundsen
- b) Robert Scott
- c) Ranulph Fiennes

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## Letter of the Month

# Forgetful science

■ Dear HIW,

Your magazine is great! I really enjoy reading it. I would like to know – how do humans forget things? I hope that you can answer my question!

Joe Small (aged 11)

**There are several different ways the brain can forget things. When you learn or experience something, new connections, called synapses, form between the neurons in your brain to make memories. However, this process can be disrupted by a molecule called the musashi protein, causing you to forget it. This often happens when you try to actively remember an event as it helps you to**

**forget related memories so that you can remember the original one better.**

**It is also possible to forget a memory as it forms. The neurotransmitter dopamine acts on the receptors in your brain to help them make memories, but afterwards it can act on another receptor to make you forget them. The memories that are forgotten are most often ones that do not have something significant, such as an emotion or smell, attached to them, as we consider them to be less important.**

Forgetting things helps to prevent our brains from becoming overwhelmed with useless information



## What's happening on...

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@HowItWorksmag Just got issue 84. Great story on pirates!

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Thank you to @HowItWorksmag for the feature of the TU 523 in your latest edition!

## Fans aren't cool

■ Dear HIW,

I love reading your magazine and get it every month! It's so interesting! Here's my question; when you turn on a fan, the air around it is warm, but if you stand next to it, it feels cold. Why does it not just blow the warm air back out?

Josh Fincher (aged 11)

Actually, the fan does just blow the warm air back out! Fans don't make the air colder; in fact, they make it warmer as the motors inside the fan give off heat. The way they work to cool you down is by creating something called the wind chill effect. When you're hot, your body sweats,

and that sweat evaporates off your skin, taking heat energy with it to cool you down. By blowing air over your skin, fans work to speed up the evaporation process, helping you feel cooler quicker.



## Hybrid power

■ Dear HIW,

I am a big fan of your magazine and have been getting it for a few years now. I have always been wondering, what are hybrid cars, and how do they work?

Jacob Samson (aged 13)

A hybrid car contains both an electric

motor and a petrol or diesel engine. When very little power is needed, such as when driving at low speeds, only the electric motor is used. However, for heavy acceleration, both work together to increase the power. When braking or stationary, the engine powers a generator to produce electricity. This recharges the battery that powers the electric motor.

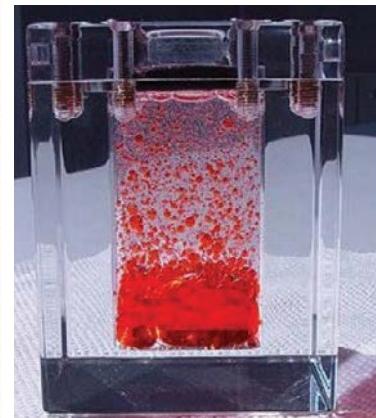
## Zero gravity mixtures

■ Dear HIW,

I've been subscribing to your magazine for a couple of years now, and I love the way that it feeds my general knowledge. I was wondering what would happen to a mixture of oil and water on board the ISS?

Jack Wright (aged 15)

Oil and water are immiscible fluids, meaning they do not mix together. They also have different densities and this is why the less dense water floats on top of the denser oil here on planet Earth. However, when there is little or no gravity, such as on board the ISS, something very different happens. Without a force pulling the denser oil to the bottom, it simply forms into bubbles that are suspended within the water. The only way to separate them is to spin the container, creating centrifugal force, which pushes the oil to the bottom, leaving the water at the top.



NASA has run experiments with oil and water on the ISS to see how they interact

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# FAST FACTS

Amazing trivia to blow your mind

## \$250,000

The cost of a ticket for Virgin Galactic's SpaceShipTwo

**THE LUNGS  
ARE THE ONLY  
ORGAN IN  
THE HUMAN  
BODY THAT  
CAN FLOAT  
ON WATER**

George Washington built the largest whisky distillery in the US at the time, producing over 40,000 litres per year

**THE WORLD'S BIGGEST  
GOLD COIN WEIGHED  
ONE TON AND WAS  
ISSUED AS AUSTRALIAN  
LEGAL TENDER**

## 35,000

The number of children under 12 that lived and worked in workhouses in Britain in 1861

*"The powerful magnetic field of Jupiter creates fantastic aurorae at its poles that are bigger than the entire Earth"*

ANCIENT GREEK ACTORS WORE MASKS TO SHOW EMOTIONS

## 23,000

The number of tanks involved in the 1943 Battle of Kursk, the largest tank battle in history

Recycling one glass bottle saves enough energy to power a computer for 25 minutes

QUEEN ELIZABETH I USED HEAVY MAKE-UP TO HELP HIDE SMALLPOX SCARS ON HER FACE

## 507

YEARS OLD

The age of Ming the deep-sea clam, the oldest living animal ever recorded

**A DAY ON VENUS LASTS LONGER THAN A YEAR**

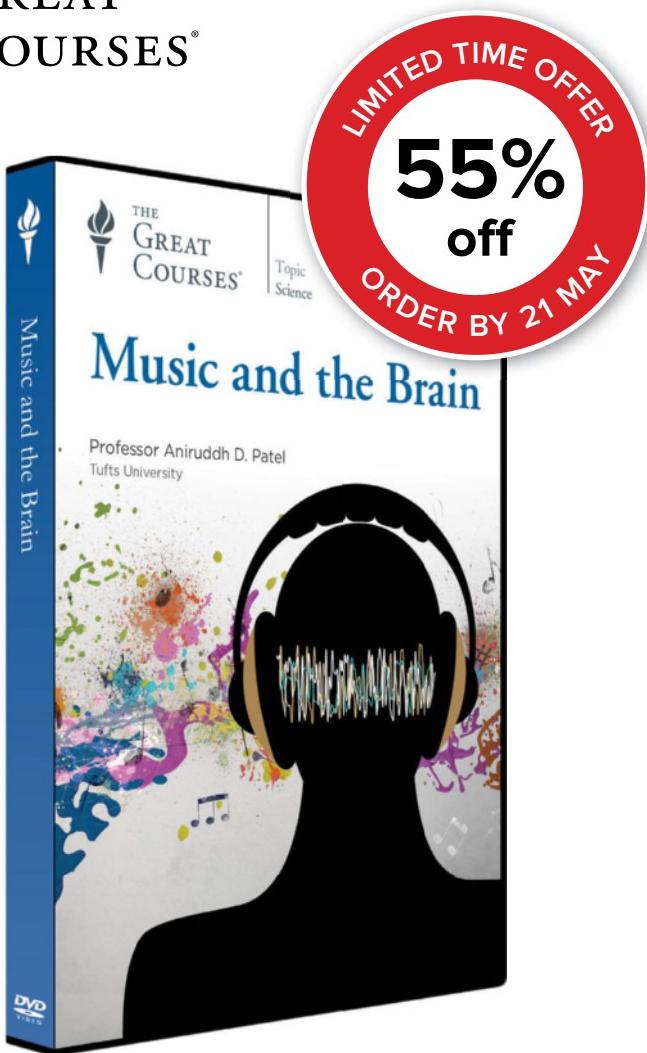
## 1.2 METRES LONG

Neil Armstrong's first step onto the Moon

VENUS FLYTRAPS GLOW BLUE TO LURE THEIR PREY

CAPTAIN COOK KEPT HIS CREW'S VITAMIN C LEVELS UP BY FEEDING THEM SAUERKRAUT AND MALT EXTRACT

*"Joyxee Island floats just off the coast of Mexico on top of 100,000 plastic bottles"*



## Are Humans Wired for Music?

Are we born with our sense of music? What gives mere tones such a powerful effect on our emotions? Why does music with a beat give us the urge to move and dance? How and why did musical behaviour originate? Music is intimately woven into the fabric of our lives, yet we still ponder these deeply puzzling and provoking questions.

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8. Arousing Expectations: Melody and Harmony
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10. Perceiving and Moving to a Rhythmic Beat
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